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The So-Called Royal Stars of Persia

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And to thy most beauteous body do we make our deep acknowledgements, O Ahura Mazda,—to those stars which are thy body.
*Gatha Haptanghaiti,** 6

In the year 1771 Anquetil-Duperron, the great French Orientalist, published the first translation of the sacred books of the Persians ever made into a European language (*Zend-Avesta, ouvrage de Zoroastre*). As will appear in the following discussion, this work contained the names of certain stars, constellations, and lunar mansions, and although he did not attempt to identify or translate the names of any of the lunar mansions and zodiacal constellations, he did attempt to identify two of the four prominently mentioned "stars," and these identifications were correct.

It was, of course, natural that some of his countrymen should have been among the first to further translate and interpret those sacred writings, and it was also natural that several French astronomers should have attempted to discuss the meaning of those passages which referred to the stars. First attempts, however, are seldom completely satisfactory, and the applications of the four names, noted by Anquetil, to the stars were something to conjure with. Instead of following the course indicated by him, these writers decided to chart courses of their own, and the confusion resulting therefrom has existed in the minds of writers on astronomy to the present time.

Only four years after the appearance of the *Zend-Avesta,* Jean Sylvain Bailly, an exceedingly interesting, if not always accurate, writer on astronomy, and whose throat became too intimately connected with the blade of the guillotine in 1793, published his *Histoire de l'Astronomie Ancienne* (Paris, 1775). He attempted to prove that the astronomy of the Persians began about 3209 B.C., and that, as Aldebaran, Antares, Regulus, and Fomalhaut marked approximately the equinoxes and solstices at that time, they must have been the four "great stars" mentioned by the Persians as "Taschter, who guards the east, Satevis, who guards the west, Venant, the south, and Haftorang, the north" (these are the names as transliterated by Anquetil, ho believed cor-

*In this word, as well as in numerous other places in this paper, some of the vowels are marked as long. We are unable at present to secure the type forms to represent these diacritical markings. With the author's permission we are proceeding without them, thus failing to indicate this refinement in the manuscript.—EDITOR.

rectly that Taschter was Sirius and Haftorang, Ursa Major). Bailly goes on to say that "Taschter is so indisputably Aldebaran that it is among the Persians the genius who presides over the rain," and he comes to this conclusion solely on the analogy of the rainy character of the Hyades among the Greeks, conveniently forgetting that we know nothing about the Greeks of 3209 B.C. (*Cf.* the passages on pages 13, 130, 480, and 481).

Bailly was followed by the prolific French writer Charles François Dupuis, who had some further views of his own regarding these "stars." He states that about 2500 B.C. "four beautiful stars seem to have been placed by nature so as to fix the limits of the seasons. All four were of the first magnitude, and two of the stars were red and two were white. The two red stars, Aldebaran and Antares, were in the signs of the equinoxes; the two others, Regulus and Fomahant, corresponded to the signs of the solstices . . . These stars received the pompous denomination of royal stars" (*Origine de tous les cultes,* I. 257-259, Paris, 1822, first published in 1794). This is the first reference that I have been able to find to the phrase "royal stars," and Dupuis says that they were the four stars placed by Ormusd at the four corners of the sky (*Ibid.,* 529-530). He also repeats the same names as Anquetil, but contradicts himself on several occasions when referring to Taschter and Haftorang, saying that "Sirius has been established as the sentinel or advance guard of the stars," and "Haftorang is an angel who takes his name from the stars of the Bear" (*Ibid.,* I. 513, II. 69; see also VI. 293, 307, 331).

Then followed François Arago, who continued the tradition of the royal stars in his popular books on astronomy. "Aldebaran of the Bull, Antares of the Scorpion, Regulus of the Lion, and Fomalhaut of the Southern Fish divide the sky into four almost equal parts. These four stars, very brilliant and very remarkable, called therefore *(aussi)* royal stars, were, without doubt, the four guardians of the heavens of the Persians in the year 3000 B.C." (*Astronomie Populaire,* I. 342, Oeuvre posthume, Paris and Leipzig, 1861).

Camille Flammarion, finally, continued to write about the royal stars, and repeated, almost word for word, the remarks of the preceding French writers *(Histoire du Ciel,* 142-143, Nouvelle Édition, Paris, 1872).

The thesis of these French writers may be fairly summed up as follows: Aldebaran, Antares, Regulus, and Fomalhaut marked the equinoxes and solstices in the year 3000 B.C.; *therefore,* these four stars were the ones mentioned by "Zoroaster" in the sacred books of the Persians; *therefore,* they were the four "royal stars"; and, *therefore,* Persian astronomy existed at least as far back as 3000 B.C. It was as simple as that. Or was it? We shall see.

It is needless to say that the idea of "royal stars" was an attractive one and appealed immensely to the imagination of astronomers, both

professional and amateur; and it was not long before reports of them began to appear in English and American works on the constellations. Garrett P. Serviss, for example, in a beautiful passage describing Regulus, and in keeping with the spirit of the tradition, says that "Cyrus, in his conquering marches, may have looked to that star for help and inspiration, for it was the heavenly guardian of the Persian monarchs" (*Round the Year with the Stars,* 36, New York and London, 1910). See also the many references in Richard Hinkley Allen, *Star-Names and Their Meanings,* 59, 66, 67, 100, 122, 181, 256, 346, 366, 369, 370, 385, 432, New York, London, etc. 1899. The passages in William Tyler Olcott's *Star Lore of All Ages* may also be consulted; see, for example, pages 7, 8, 15, 40, 234, 236, 327, 329, 341, New York and London, 1911. A careful comparison of the passages referred to above, one with another, will show how confused the subject was in the minds of these two authors, because many of the secondhand authorities consulted by them were entirely unreliable.

Practically all writers on the constellations since 1900 have followed Allen without asking any questions or examining the original records: the line of least resistance always invites error to follow error. The tradition has been so widely accepted that even the professional astronomer will, on occasion, mention the "Royal Stars" before learned societies (*Publications of the Astronomical Society of the Pacific,* **55**, 177, 1943). The latest reference to these "stars" will be found in *Sky and Telescope,* Vol. III, No. 6, page 5, 1944.

Without going into further detail, I can safely say that the present form of the tradition is substantially set forth in the following statement: "Aldebaran, Antares, Regulus, and Fomalhaut were the four Royal Stars of Persia about the year 3000 B.C."

How did this idea of the "Royal Stars of Persia" originate, and is it based on any historical evidence? What are the "ancient Persian records" referred to by so many writers? The whole matter, of course, can be traced back very easily to several passages in the *Bundahish,* a work which, unfortunately, seems to have been consulted by very few astronomical writers. This name, which means "Creation of the Beginning" or "Original Creation," is applied by the Parsees to a Pahlavi work which appears to be a collection of fragments relating to the cosmogony, mythology, and legendary history of the ancient Persians and the worship of Ahura Mazda; and although the work, as we have it, could not have been completed until after the Muhammadan conquest of Persia in 651 A.D., it is possible that some of the myths and legends contained in it are older than Zarathushtra himself. Many passages have the appearance of being translations of an Avestan original, possibly the lost *Damdad Nask,* one of the twenty-one books into which the whole of the Zoroastrian scriptures are said to have been divided before the time of Darius (*Sacred Books of the East,* hereafter referred as to *SBE,* V. xxii, xxiv, xlii, Oxford, 1880. The translation which

follows is by E. W. West, the great English Pahlavi scholar).

After Auharmazd created the twelve constellations of the zodiac (*Akhtar*) and the twenty-eight lunar mansions (*Khurdak-i hamarikan*, literally, "fragments of the calculators"), the narrative continues as follows:

"4. And all his original creations residing in the world are committed to them (the constellations); so that when the destroyer (Aharman) arrives, they overcome the adversary and their own persecution, and the creatures are saved from those adversities.

"5. As a specimen of a warlike army, which is destined for battle, they have ordained every single constellation of those 6480 thousand small stars as assistants; and among those constellations four *chieftains*, appointed on the four sides, are *leaders*.

"6. On the recommendation of those *chieftains* the many unnumbered stars are specially assigned to the various quarters and various places, as the united strength and appointed power of those constellations.

"7. As it is said that Tishtar is the chieftain of the east, Sataves the chieftain of the south, Vanand the chieftain of the west, and Haptokring the chieftain of the north.

"8. The great one which they call a Gah, which they say is the great one of the middle of the sky, till just before the destroyer came, was the midday one of the five, that is, the Rapitvin (*Bundahish*, II. 4-8).

I have given a full translation of the relevant passages to enable the reader to have the complete story before him. The italics in Sections 5 and 6 are my own and will be referred to later.

In the study of Pahlavi and Pazand works it is always desirable to discover, if possible, the original Avestan forms. Sometimes this is exceedingly difficult, but in the present case the task is a simple one, for the Avestan names of the four chieftains are well known. They are Tishtrya, Satavaesa, Vanant, and Haptoiringa. But before discussing these names individually, it is necessary to consider the statement in the tradition which carries us back to the year 3000 B.C.

A very pertinent question arises at this point: "What do we *actually* know about Persia and the Persians of 3000 B.C.?" The answer is "Nothing." I am not interested here in inferences to be drawn from the Vedas or works of other Aryan nations: I am interested only in historical records (too long strangers to writers on the constellations) which refer to the people we have come to know as the Persians. Let me summarize the facts very briefly.

The first voice that we hear is that of Zarathushtra speaking through the Gathas. For my present purpose it is unnecessary to discuss the question as to whether Zarathushtra was a Persian or a Magus. Most Avestan scholars are agreed, however, that he was an Aryan and that

the Magi, the "Levites of the Zoroastrians," took over and adopted those parts of his religion which best suited their purposes after the death of the Prophet. This, in turn, brings up the period during which Zarathushtra lived. According to the mediaeval Persian tradition he was born in 660 and died in 583 B.C. (See A. V. Williams Jackson, *Zoroaster, the Prophet of Ancient Iran,* 15, 16, London, 1899, and the authorities quoted by him, and the table of Zoroastrian chronology compiled by West in *SBE,* XLVII. xxviii-xxxi). It is well recognized by Persian scholars, however, that 660 B.C. should be regarded as a minimum antiquity, for an earlier date seems to be required to bring the Gathas nearer the *Rig-Veda,* to allow for the interval between the earliest Gathas and the *Gatha Haptanghaiti,* and, finally, to allow for the considerable development which must have taken place between the Yasnas and the later Yashts, which probably appeared sometime before the cuneiform inscriptions of Darius (James Hope Moulton, *Early Zoroastrianism,* 19-22, London, 1913; L. H. Mills in *SBE,* XXXI. xxxii-xxxv and 282; P. M. Sykes, *A History of Persia,* I. 109, London, 1915). Professor Moulton and others, therefore, plead eloquently for a much earlier date ("Nothing later than the tenth century B.C. can be admitted," Moulton, *The Treasure of the Magi,* 6, 13, Oxford University Press, 1917). Let us, consequently, push back Zarathushtra's birth 300 years to 960 B.C. Will this help the cause of the tradition? Obviously not, for the Gathas do not contain a single reference to any individual star or constellation; in fact, nearly all myths are dropped, and even the old Aryan gods, who appear in the later Yasnas, *Vendidad,* and Yashts, are, with one exception, wholly absent. And Persia, as a nation, cannot, by any stretch of the imagination, be said to have stepped upon the stage of history until the accession of Achaemenes about 650 B.C. (P. M. Sykes, *Ibid.,* I. 151, 152). There is, therefore, no historical basis whatsoever for speaking of the stars and constellations which were known to the Persians in the year 3000 B.C. Apropos of early dates, I recall a statement of Max Müller regarding the age of the *Rig-Veda*: "What should we gain if we could date the Veda back to 6000 or 4000 B.C.? Beyond 2000 B.C. all is *tohu va bohu,* emptiness and darkness, mere vanity and vexation of spirit, without a ray of light from anywhere" (*Contributions to the Science of Mythology,* II. 430, London, New York and Bombay, 1897). If this is true of the *Rig-Veda, a fortiori* it is true of the *Avesta.*

Now let us consider the four chieftains. Tishtrya is the great Rain-star of the ancient Persians, "who from the shining east moves along the path made by the gods, along the way appointed for him," and is the name of Sirius, "whom Ahura Mazda has established as a lord and overseer above all stars . . . I, O Spitama Zarathushtra, have created that star Tishtrya as worthy of sacrifice, as worthy of prayer, as worthy of propitiation, as worthy of glorification as myself, Ahura Mazda!" He is also a Yazata, "adored one," and assists in guiding the forces

of nature, especially with regard to the refreshing rains, giving the fields "their share of the waters." We find a beautiful description of Tishtrya where he is mentioned as "the bright and glorious star, that gives happy dwelling and good dwelling; the white, shining, seen afar, and piercing . . . piercing from afar with its shining undefiled rays (*Tir Yasht,* 35, 44, 50, 1, 2). His victory over Apaosha, the Daeva of drought, as told in his Yasht, is a vivid and picturesque account, hardly equalled elsewhere in Persian literature. Tishtrya, being the brightest star in the sky, and "the first star," needs no other stars for companions, and, as we shall see, he is the only *star* among the four chieftains. And be it noted that Sirius is *not* mentioned in the tradition as one of the "royal" stars.

I do not believe that I have ever seen a translation of the word Tishtrya. There appear to me, however, to be two possible derivations. The Sanskrit word Tishya, which appears twice in the *Rig-Veda* (V. 54. 13 and X. 64. 8), is one of the names of the 6th Hindu Nakshatra, or lunar mansion, which consisted of Praesepe and γ, δ, η, and θ Cancri; the equivalent Persian lunar mansion was called in Pazand, very appropriately, Avra or Avrak, from the Avestan Awra, "the little cloud," whose heliacal rising was said to coincide with that of Tishtar. Tishya means "fortunate, auspicious, happy, prosperous," etc. On the reasonable assumption that both Tishya and Tishtrya developed from the same original Indo-Iranian or Indo-European form, at a time when the Aryans of both India and Persia shared a common religion and a common culture, the meaning of Tishtrya would be "the lucky or prosperous (star)," that is, for the Aryan nations. The other possibility is this: Tashtar is a modern Persian word meaning "cloud" and "the angel who has charge of rain and plants" (F. Steingass, *Persian-English Dictionary,* 302, London, 1892). If this meaning was carried over from the Pahlavi Tishtar, and it, in turn, preserved that meaning from the Avestan Tishtrya, then we may properly call Sirius "the cloud (star)," signifying, of course, one filled with rain. Both meanings would be appropriate, but I am inclined to favor the former. In this connection I should like to refer to a passage in the *Dina-i Mainog-i Khirad,* hereafter referred to as *DMK,* XLIX. 4-6: "The spirit of wisdom answered thus: 'Of the stars which are in the sky the first star is Tishtar. . . . And prosperity of every kind and the fertility of the world are in the path of Tishtar.'" And to the same effect regarding Tishya, see *The Institutes of Vishnu,* LXXVIII. 13: "By performing a Shraddha under the Nakshatra Tishya he procures prosperity," and also *Apastamba,* II. 8. 20. 3: "He who desires prosperity shall fast in the half of the year when the sun goes to the north under the constellation Tishya." The Hindu name Tishya can still be recognized in the modern Buddhist Tissa, but, because of precession, it is no longer the name of the 6th Nakshatra. For the rather peculiar connection between Tishtar and the constellation Kalachang, the modern Persian Kharchang,

i.e., Cancer, see *Bundahish*, VII. 1. 2 and *Zad Sparam*, VI. 1.

Satevaesa, meaning "one hundred dwellings or habitations," is the name of the constellation Aquarius, including Fomalhaut (Kavasji Edalji Kanga, *A Dictionary of the Avesta, Gujerati, and English Languages*, 465, Bombay, 1900). I do not wish to anticipate future discussions any more than is necessary, but it is interesting to compare this name with that of the 23rd Hindu Nakshatra, Shatabhishaj, "one hundred physicians" (Sir Monier Monier-Williams, *A Sanskrit-English Dictionary*, 1049, Oxford, 1899; *Taittiriya Sanhita*, IV. 4. 10. 1-3; *Sankhayana-Grihya-Sutra*, I. 26. 23; *The Institutes of Vishnu*, LXXVIII. 30). As the title "one hundred" of anything, be they stars, dwellings, or physicians, would not ordinarily refer to a single star (in fact, one of the names of the Hindu Nakshatra is "one hundred stars," Shatatara), and as the Hindu, and the equivalent Persian, lunar mansions refer to a number of stars in Aquarius, it is obvious that we are dealing here with a constellation and not with one individual star. For the importance of Aquarius among the Sumerians and Babylonians, from whom the Persians admittedly received the zodiacal constellations, see *Popular Astronomy*, LII, 11, 1944. And the fact that Varuna, "the All-enveloping sky," who is thought by many to have been the supreme diety of the Indo-Iranians, is the presiding divinity of the Hindu mansion, is probably evidence of its great importance in early Indian astronomy (A. A. Macdonell, *Vedic Mythology*, 20-24, Strassburg, 1897).

We read of the "powerful Satevaesa, made by Mazda, who pushes waters forward," and that he "makes those waters flow down to the seven Karshvares (regions, the modern Persian Kishwar) of the earth, and when he has arrived down there, he stands, beautiful, spreading ease and joy on the fertile countries, thinking to himself: 'How shall the countries of the Aryas grow fertile?'" (*Tir Yasht*, 0, 9). We are also told that "Satavaesa comes down and flows between the earth and the sky, he to whom the waters belong, who listens to appeals and makes the waters and the plants grow up, fair, radiant, and full of light, to nourish animals and men, to nourish the Aryan nations, to nourish the five kinds of animals, and to help the faithful" (*Farvardin Yasht*, 44). From the above references it has been contended that "Satavaesa was the rain-star before Tishtrya was raised to that dignity" (Mehrjibhai Noshervanji Kuka, "The Stars Mentioned in the Avesta and the Tale They Tell" in *Zartoshti*, II. 15, Bombay, 1904. And for a sincere, but illogical and impossible, argument which seeks to identify Satavaesa with Canopus, see "The Identity of Some Heavenly Bodies Mentioned in the old Iranian Writings" by Muncherji Pestonji Khareghat in *Sir Jamsetjee Jejeebhoy Madressa Jubilee Volume*, 133-142, Bombay, 1914). Satavaesa, therefore, was the constellation Aquarius, as known to the Persians, which included Fomalhaut and probably several stars in its immediate vicinity. It will be remembered that Ptolemy, in his

Almagest, included Fomalhaut among the stars of Aquarius as well as among those of Piscis Austrinus. Rigel, Alpheratz, and Elnath were treated in a similar way (see *Ptolemy's Catalogue of Stars* by Peters and Knobel, 42, 50, 44, 34, 32, 36, The Carnegie Institution of Washington, 1915). The fact that there are 106 naked-eye stars in Aquarius, and in Piscis Austrinus east of R.A. XXII^h (1950.0), may or may not be of any significance in this connection.

Vanant, like Tishtrya, has a Yasht of his own, where we read of his being "made by Mazda, the holy and master of holiness. . . . Strong, invoked by his own name, healing, in order to withstand the accursed and most foul Khrafstras (evil creatures which are destroyed by the rain) of the most abominable Angra Mainyu" (*Vanant Yasht,* 0, 1). The people sacrificed "unto Vanant . . . to obtain the well-shapen strength, to obtain the Victory, made by Ahura, for the crushing Ascendant, for the destruction of what distresses us, for the destruction of what persecutes us" (*Tir Yasht,* 12).

The word Vanant means "smiter, stinger, seizer, conqueror, victorious one," and the play on words in the above quotation is obvious (Kanga, *Ibid.,* 520 and Darmesteter's note in *SBE,* XXIII. 97). The modern Persian equivalent would seem to be Awan of the same meaning. The Pazand Varant is the name of the 20th Persian lunar mansion which consisted of the stars in the tail of Scorpius. Here, however, we are dealing with the entire constellation as one of the four chieftains, with the "red" Antares as its principal star.

In the later Pahlavi writings it is said that "the constellation Vanand is intrusted with the passes and gates of Alburzh; so that the demons and witches and fiends may turn from those gates and passes, that it may not be possible for them to cut off and break up the road and passage of the sun and moon and stars" (*DMK,* XLIX. 12-14; and see also *Shayast La-Shayast,* XI. 4 for the part of the sacrifice which was dedicated to Vanand). According to Persian cosmology the heavenly bodies were supposed to rise and set through openings or passes (*rogin*) in the mountain range of Alburzh, which encircled the world, a concept similar to that of the Homeric Oceanus (*Bundahish,* V. 5 and *Iliad,* XXI. 195). Compare this with the 33rd Chapter of the *Book of Enoch*: "And I saw how the stars of heaven come forth, and I counted the portals out of which they proceed, and wrote down all their outlets, of each individual star by itself, according to their number, their names, their courses and their positions, and their times and their months, as Uriel the holy angel who was with me showed me."

The last of the four chieftains is possibly the most interesting of all and serves as my strongest piece of evidence. It is admittedly the "Dipper" in our Ursa Major, "those stars that are seven in number, the Haptoiringa, made by Mazda, glorious and healing" (*Sirozah,* I. 13 and II. 13). And here again we find *no* reference in the tradition to this conspicuous constellation as one of the "royal stars." There has been

a great deal of uncertainty at times over the meaning of the name of this chieftain, but there should not have been. The modern Persian name, involving slight phonetic changes from the original Avestan, is Haft Aurang, "the seven thrones," metaphorically, "the seven heavens," a cosmological idea common to most ancient peoples in one form or another (see Francis Johnson, *A Dictionary, Persian, Arabic, and English,* 182, 1394, London, 1852, and F. Steingass, *Ibid.,* 119, 1502. Consult also *Rashn Yasht,* 28; *Farvardin Yasht,* 60; *Tir Yasht,* 12; and compare *Isaiah,* xiv. 13).

Many references could be given to show that the Persians regarded the north as the habitation of demons and all sorts of evil spirits. This idea is set forth and discussed briefly in two of the Yashts mentioned above, but it reaches its greatest articulation in a later Pahlavi work where it is said that "the constellation Haptok-ring, with 99,999 guardian spirits of the righteous (an expression meaning simply a very large number; compare the Homeric "loud as 9000 warriors or 10000 cry in battle," *Iliad,* V. 858 and XIV. 148) is intrusted with the gate and passage of hell, for the keeping back of those 99,999 demons and fiends, witches and wizards, who are in opposition to the celestial sphere and constellations of the zodiac. Its motion, also, is round about hell; and its special business is this, as it were it holds the twelve signs of the zodiac by the hand, in their proper going and coming. And those twelve constellations also proceed in like manner by the power and help of Haptok-ring; and every single constellation, when it comes in at Alburzh, provides support for Haptok-ring, and begs protection from Haptok-ring" (*DMK,* XLIX. 15-21).

In order to complete this picture of the chieftains or leaders, and in order to omit nothing which might have a bearing on the whole subject, I must refer to Section 8 of the first quotation from the *Bundahish.* There seems to be no doubt that "the great one of the middle of the sky," *Mas-i Miyan-i Asman,* refers to a constellation because, like the four chieftains, it is pitted against one of the planets (Saturn) in the great struggle between the constellations and the forces of evil. A *Gah,* however, is a certain period of the day for ceremonial purposes, and the Rapitvin Gah (the Avestan Rapithwina) is the period of midday, from 10 A.M., to 3 P.M. Auharmazd, we are told, "performed the spiritual Yazhishn ceremony with the archangels (Ameshospendan, the Amesha Spentas of the *Avesta,* "the immortal holy ones") in the Rapitvin Gah, and in the Yazhishn he supplied every means necessary for overcoming the adversary" (*Bundahish,* II. 9). This midday period, however, could be celebrated only during the seven months of summer, and the reference seems to be to some constellation that must have been in the daylight more than any other during that particular period. But, as the constellation is not given a proper name, as we do not know the date when this portion of the *Bundahish* was actually written, or the exact time to which it referred, and as the constellation is not men-

tioned in the *Avesta,* it is impossible to arrive at any definite or satisfactory conclusion about it. It must be remembered also that the "five" in the quotation does not refer to this constellation *and* the four chieftains, but to the five periods of the day. This is proved by the fact that the four chieftains are nowhere equated with the other four ceremonial periods.

Do we find any reference, directly or indirectly, to "royal stars" in the above quotations from the sacred writings of the Persians? The answer is, of course, "No." There were no royal stars in the astronomy of the Persians, nor, in fact, in the astronomy of any Aryan nation of antiquity. Regulus, "the petty king," and the various Greek royal titles of the star, are ultimately Sumerian in origin, as is also the Arabian al-Maliki (*Popular Astronomy,* LII, 21, 1944). The four "stars" were known as "Chieftains" or "Leaders." The reason for this designation is perfectly obvious when it is realized that the events described in this part of the *Bundahish* took place before the appearance of man on the earth, at a time when the stars and constellations were preparing for the cosmic battle with the planets which were sent against them by Angra Mainyu, "the enemy spirit" (*Bundahish,* V. 1 and *Sikand-Gumanik Vijar,* IV. 29 and VIII. 17. The title "guardians," used by so many writers, misses the point entirely). "Those seven planets (the 'brigand planets') pervert every creature and creation and deliver them up to death and every evil" (*DMK,* VIII. 20). Thus the Persians, in their view of the planets, differed from every other ancient nation, obviously on account of Magian influence, for the Magi "were strangers alike to Aryan and to Semite."

Let us now turn back to my statement of the tradition to see what there is left of it. In the first place, Aldebaran and Regulus cannot be found among the four leaders or chieftains, and Sirius and Ursa Major are not mentioned in the tradition at all. In the second place, the four "royal stars," instead of being merely guardians, turn out to be four chieftains preparing their forces for battle against Ahriman and his myrmidons of evil; and there is not the slightest evidence in either the sacred or secular literature that any king of Persia, either historical or legendary, ever claimed for himself, or had appropriated for him, any particular stars or constellations. Thirdly, we find only one *star* among the four leaders and three *constellations.* And, lastly, when we talk of the stars and constellations which were known to the Persians of 3000 B.C., we are dealing not only with vague and uncertain inferences, but also with an utterly unknown quantity, and such speculations have no historical value whatsoever in researches of this kind. Even if we date the Gathas, the Yashts, and the early parts of the *Bundahish* two thousand years before the ministry of Zoroaster, there is still no evidence of Royal Stars.

(NOTE: Under present conditions it was impossible to secure a copy of Anquetil's original work in French. I did, however, use an excellent

German translation by Johann Friederick Kleuker under the title *Zend-Avesta, Zoroasters Lebendiges Wort*, 3 Vols., Riga, 1777, Vol. I, 2nd Ed., 1786.)

Clusters of Five Planets

By R. B. WEITZEL

Clusters of the five planets—Mercury, Venus, Mars, Jupiter, and Saturn—occur seldom. A search was instituted to determine when the planets were visible in a field of less than ten degrees. As an aid to that search, the approximate conjunctions of Mars, Jupiter, and Saturn were computed for the period from 3000 B.C. to 2000 A.D., with the result that a hundred and fifty such cases became available for consideration. A number of trials were made to bring Mercury and Venus into the design, but only four distinct configurations were found to conform to the requirement that all five planets be visible in a relatively small compass. The clusters that were located occurred in the years 710 A.D., 185 B.C., 1059 B.C., and 1953 B.C. They will be treated in that order.

On June 25, 710 A.D., Mercury, Venus, Mars, Jupiter, and Saturn were closely grouped, but then the heliacal setting of Mars, that is, its last appearance as an evening star, occurred for a geographic latitude 32° north; accordingly, in this instance, a more southerly base, the Maya region of Middle America, 90° west longitude, 20° north latitude, was used for computation. The following are the places of the planets and sun on June 25, 710 A.D., at 7:20 P.M., forty minutes after sunset.

	L	b	λ	β	α	δ
Mercury	246°.23	−3°.83	117°.23	−2°.71	118°.76	+18°.20
Venus	147.63	+3.35	117.32	+1.53	119.74	+22.34
Mars	127.62	+1.86	115.88	+1.20	118.15	+22.30
Jupiter	126.07	+0.86	121.37	+0.74	123.91	+20.69
Saturn	117.74	+0.67	115.65	+0.61	117.75	+21.65

	⊙	M.L.	Eq. T.		
Sun	96°.45	96°.98	+0°.04	97°.02	+23°.45

It may be noted that the maximal difference in geocentric longitude is 5.7 degrees. The stellar magnitude, the hour angle, altitude and azimuth at 7:20 P.M., and the time of setting, without refraction, of each planet, are given.

	Mag.	H.A.	Alt.	Az.	Setting
Mercury	+1.4	88°.22	7°.73	73°.38	7.55 P.M.
Venus	−3.3	87.24	9.90	69.67	8.05 P.M.
Mars	+1.9	88.83	8.48	69.28	7.59 P.M.
Jupiter	−1.4	83.07	13.03	72.44	8.19 P.M.
Saturn	+0.6	89.23	7.93	69.78	7.56 P.M.

A geographic base, 45° east longitude, 32° north latitude, the Baby-

Ionian area, was used to compute the data of the remaining clusters. On March 25, 185 B.C., the planets were morning stars. The following are the places of the planets and sun at 5:30 A.M., thirty-two minutes before sunrise.

	L	b	λ	β	α	δ
Mercury	244°.63	—4°.66	334°.06	—2°.36	336°.33	—11°.00
Venus	277.58	—2.20	327.46	—1.23	329.84	—12.83
Mars	314.72	—1.87	333.97	—1.18	336.35	—11.26
Jupiter	329.11	—1.35	334.33	—1.15	336.69	—11.10
Saturn	324.06	—1.96	327.43	—1.80	329.87	—13.01

	⊙	M.L.	Eq. T.		
Sun	1°.03	359°.19	+1°.75	0°.94	+0°.41

The maximal difference in geocentric longitude is 6.9 degrees. The stellar magnitude, the hour angle, altitude and azimuth at 5:30 A.M., and the time of rising of each planet, are given.

	Mag.	H.A.	Alt.	Az.	Rising
Mercury	+0.5	74°.65	6°.85	107°.56	4.56 A.M.
Venus	—3.5	68.15	10.97	112.80	4.35 A.M.
Mars	+1.3	74.66	6.70	107.76	4.57 A.M.
Jupiter	—1.6	75.00	6.52	107.45	4.58 A.M.
Saturn	+1.2	68.18	10.83	112.95	4.36 A.M.

On May 28, 1059 B.C., the planets were evening stars. The following are the places of the planets and sun at 7:30 P.M., forty-five minutes after sunset.

	L	b	λ	β	α	δ
Mercury	199°.52	—0°.88	78°.88	—0°.58	77°.93	+22°.88
Venus	123.30	+3.22	82.92	+1.59	82.17	+25.23
Mars	88.98	+1.71	76.54	+1.10	75.21	+24.24
Jupiter	82.89	+0.32	78.61	+0.27	77.54	+23.68
Saturn	85.53	—0.07	82.64	—0.06	81.97	+23.57

	⊙	M.L.	Eq. T.		
Sun	55°.77	55°.96	—2°.60	53°.36	+19°.52

The maximal difference in geocentric longitude is 6.4 degrees. The stellar magnitude, the hour angle, altitude and azimuth at 7:30 P.M., and the time of setting of each planet, are given.

	Mag.	H.A.	Alt.	Az.	Setting
Mercury	+1.1	90°.53	11°.47	70°.07	8.29 P.M.
Venus	—3.4	86.30	16.00	69.90	8.53 P.M.
Mars	+1.9	93.25	10.00	67.58	8.22 P.M.
Jupiter	—1.5	90.92	11.57	69.17	8.30 P.M.
Saturn	+0.5	86.49	15.03	71.33	8.47 P.M.

In 1953 B.C., Mercury, Venus, Mars, Jupiter, and Saturn were visible for twenty-seven mornings, from the heliacal rising of Saturn on February 19 to the heliacal setting of Mercury on March 16 of that year. The following are the places of the planets and sun on February 26, at 6:00 A.M., fifty-two minutes before sunrise.

	L	b	λ	β	α	δ
Mercury	199°.25	—2°.07	293°.21	—1°.12	295°.35	—22°.99
Venus	254.07	—1.83	293.38	—0.91	295.48	—22.74
Mars	273.63	—1.87	293.20	—1.18	295.35	—23.04
Jupiter	284.36	—0.96	290.21	—0.82	292.07	—23.18
Saturn	291.22	—1.39	293.94	—1.27	296.15	—23.00

	⊙	M.L.	Eq. T.		
Sun	320°.78	318°.77	+4°.50	323°.27	—14°.85

The planets had similar declinations and, led by Jupiter, rose at very nearly the same place on the horizon. The stellar magnitude, the hour angle, altitude and azimuth at 6:00 A.M., and the time of rising of each planet, are given.

	Mag.	H.A.	Alt.	Az.	Rising
Mercury	+0.6	66°.58	5°.93	121°.87	5.28 A.M.
Venus	—3.4	66.71	6.00	121.60	5.28 A.M.
Mars	+1.3	66.58	5.90	121.91	5.28 A.M.
Jupiter	—1.6	63.30	8.15	123.93	5.15 A.M.
Saturn	+0.7	67.38	5.34	121.42	5.31 A.M.

The five planets provided a magnificent spectacle. Mercury, Venus, and Mars approximated a triple star; Saturn was somewhat lower and to the left; while Jupiter, more apart, shone above and to the right of them. On the morning of February 26, 1953 B.C., Mercury, Venus, Mars, Jupiter, and Saturn were clustered in a field of three and eight-tenth degrees—an exceptionally dense assemblage of planets.

The planetary configurations of 710 A.D., 185 B.C., 1059 B.C., and 1953 B.C., probably are the only occasions, during the past five thousand years, when Mercury, Venus, Mars, Jupiter, and Saturn were visible in clusters with maximal difference in geocentric longitude of less than seven degrees.

Tables and Formulas

P. V. Neugebauer: Chronologie II, 1914.
Corrections E-1, 1929.

Karl Schoch: Planeten-Tafeln, 1927.

U. S. Hydrographic Office, No. 200, 1928.

1) $\tan \odot A = \tan L \cos \epsilon$
2) $\sin \odot D = \sin L \sin \epsilon$
3) $\tan M = \tan \beta / \sin \lambda$
4) $\tan \alpha = [\cos (M + \epsilon) \tan \lambda] / \cos M$
5) $\tan \delta = \sin \alpha \tan (M + \epsilon)$
6) $\text{hav } z = \text{hav } t \cos \phi \cos \delta + \text{hav } (\phi \sim \delta)$
7) $h = 90° - z$
8) $\sin Az = (\sin t \cos \delta) / \cos h$
9) $\cos t_o = -\tan \phi \tan \delta$

ϕ = geographic latitude
t = hour angle from meridian
t_o = semi-diurnal arc.

Washington, D. C.

Easter Intervals

By GEORGE W. WALKER

Peter Easter, who lives on Easter Island, was born on Easter day in 1908. He has three children, all boys, all born on Easter days.

Pete, the eldest, was born on April 1, 1934. He celebrated his eleventh birthday anniversary this year on Easter day. Eleven years from now, he will have another birthday celebration on Easter.

His younger brother, Repete, is doing much better. He was born on April 9, 1939. He has already celebrated one birthday on Easter, last year. In another five years he will do it again.

Peter Easter himself was born on April 19, 1908. The first return of Easter on his birthday will not be until 1981, when Peter will be 73 years old. It is hard for Peter to believe that, in the long run, Easter comes more often on April 19 than on any other day.* Just now, this day seems badly neglected in Easter returns.

The whole Easter family is feeling sorry for the youngest boy, Threepete, who was born (on Easter) on March 24, 1940. He will not see another return of Easter on his birthday unless he lives to be 451 years old, in 2391 A.D.

Peter Easter's wife, before her marriage, was Kitty Christmas. She was born on a Christmas day, and celebrates her birthday on Christmas every year.

Peter and Kitty Easter were married in the United States on Thanksgiving Day; but we won't go into that.

The interval that must elapse between successive returns of Easter to the same calendar day is one of the features of the Gregorian calendar which is intriguing because, determined by definite rules, it seems completely erratic and baffling. Easter intervals may be of special interest to that fraction of our population, some twelve million, who have birthdays within the Easter season, and particularly to the third of a million who were born on Easter day. To all of us they offer a mathematical puzzle out of everyday life. This article aims to study the peculiar ways of Easter intervals and to reduce them to a definite understanding.

One of the first discoveries we make about Easter intervals is that our most natural guesses are wide of the truth. For instance, we might, most simply, start from the information that there are just 35 calendar days (from March 22 through April 25) on which Easter can occur, and, supposing that each should be visited in regular turn, conclude that Easter must return to any of them after just 35 years, every Easter

*See "Rare Dates For Easter" by George W. Walker, POPULAR ASTRONOMY, Vol. LII, No. 3, March, 1944.

interval being of the same length. The only kernel of truth in this naive view is that the average of all Easter intervals must, necessarily, be 35 years. Even this does not carry over the specific calendar days. The average interval for specific days ranges from somewhat less than 26 years for April 19, the most favored day, to nearly 207 years for March 22, the rarest of Easter days.*

We would really be more likely to guess, *a priori*, that the complicated conditions determining Easter in our Gregorian calendar—and we all know they are complicated—would so interact as to produce a random pattern of intervals. We would expect a typical probability figure, with, most likely, the interval 35 years at the peak as the most frequent interval, with 34 and 36 not quite so common, and so shading down to the relatively infrequent small or very large intervals. This is excellent probability reasoning, but it happens to be also very far from the truth.

Let us take an example to show how wrong this guess is. Consider the interval 36 years, which we might expect to hold a very high position in the probability pattern. Any set of 36 consecutive years must include exactly 9 years whose year numbers are divisible by four. All of these, with possibly one exception (if the set includes an exceptional century year), must be leap years. So there must be in any interval of exactly 36 years a total of 36×365 days plus 9 or 8 extra days, that is, either 13149 or 13148 days in all. This figures out to 1878 full weeks plus 3 or 2 extra days. So any calendar day which is Easter Sunday at the beginning of the interval must be on Wednesday or Tuesday after exactly 36 years. Therefore that calendar day can not be Easter again. So there can never be an Easter interval of exactly 36 years. The same is true also of the 37-year interval and of others that we might expect to occur very often on our *a priori* reasoning based on probabilities and conjecture.

We have herein not only proved our first guesses wrong but also made a start on finding valid Easter intervals. One requirement for a valid interval must be that it can bring the same calendar day in the Easter season to a Sunday again. Let us see where this leads us.

An ordinary year has 365 days, or 52 weeks and one day over. If a given calendar day is Sunday in one year, it will ordinarily be Monday the next year. If the extra day of leap year intervenes, this pushes the day ahead to Tuesday. So we can figure ahead from year to year, and see how soon the same calendar day can be Sunday again.

We find that it makes a difference where we start, particularly whether we start from a leap year (after February 29, of course) or from a year next after or second or third after a leap year. Let us group like years together and label each group with its "quartic remainder" (QR, for short), that is, the remainder left after dividing the

ibid.

number of the year by 4. If the QR is 0, ordinarily we have a leap year. And to simplify our first step let us, for the present, suppose that we are back on the Julian calendar where every fourth year is a leap year regardless.

Now we find our step by step procedure looking like one of the rows of Table I, in which the asterisk (*) marks the double jump due to the extra day of a leap year.

TABLE I

DAY OF THE WEEK OF A GIVEN CALENDAR DAY THROUGH SUCCESSIVE YEARS

INTERVAL:	0	1	2	3	4	5	6	7	8	9	10	11	...
QR = 0 :	*Sun*	Mon	Tue	Wed*	Fri	Sat	*Sun*	Mon*	Wed	Thu	Fri	Sat	...
1 :	*Sun*	Mon	Tue*	Thu	Fri	Sat	*Sun**	Tue	Wed	Thu	Fri*	*Sun*	...
2 :	*Sun*	Mon*	Wed	Thu	Fri	Sat*	Mon	Tue	Wed	Thu*	Sat	*Sun*	...
3 :	*Sun**	Tue	Wed	Thu	Fri*	*Sun*	Mon	Tue	Wed*	Fri	Sat	*Sun*	...

If we carry out Table I far enough, and then pick out the intervals that bring returns of Sunday, we find four lists like those given in Table II.

TABLE II

INTERVALS GIVING SUNDAY RETURNS

(as in the Julian calendar; no century common years)

QR = 0 :	0	6		17	23	28	34		45	51	56	62		73	79	84	...
1 :	0	6	11	17		28	34	39	45		56	62	67	73		84	...
2 :	0		11	17	22	28		39	45	50	56		67	73	78	84	...
3 :	0	5	11		22	28	33	39		50	56	61	67		78	84	...

The repeating pattern in Table II is obvious; and it should not surprise us that the whole pattern repeats every 28 ($= 4 \times 7$) years. The same set of differences between terms appears in each of the four rows, namely, in cycle, 11, 6, 5, and 6 years.

For our convenience later, we can condense Table II into a single list by indicating in parentheses after each term the quartic remainder or remainders with which it appears. This has been done in Table III.

TABLE III

INTERVALS GIVING SUNDAY RETURNS

(including no century common years)

0(0123),
5(3), 6(01), 11(123), 17(012), 22(23), 23(0), 28(0123),
33(3), 34(01), 39(123), 45(012), 50(23), 51(0), 56(0123),
61(3), 62(01), 67(123), 73(012), 78(23), 79(0), 84(0123),
...

Now let us take into account the century common years, one of which occurs at every hundredth year unless its century number also is divisible by 4.

If there is a century common year included in the interval, it will mean that one single step will be substituted for one of the double jumps in Table I, so that thereafter the days marked Sunday in Table I will be Saturday, and the days marked Monday will be Sunday. All we need to do, therefore, is to pick out the Mondays in Table I which come after at least one asterisk, and proceed as before. The end result is a list of possible Sunday intervals shown in Table IV.

TABLE IV

INTERVALS GIVING SUNDAY RETURNS

(when a century common year is included)

6(23), 7(0), 12(0123),
17(3), 18(01), 23(123), 29(012), 34(23), 35(0), 40(0123),
45(3), 46(01), 51(123), 57(012), 62(23), 63(0), 68(0123),
73(3), 74(01), 79(123), 85(012), 90(23), 91(0), 96(0123),
...

We may notice that the average Easter interval, 35 years, has at last appeared in Table IV among the intervals which can bring a Sunday return if the conditions are just right. The year from which the 35-year interval starts must be divisible by 4, and the interval must include one of the century common years. With these restrictions, the 35-year interval is, naturally, comparatively rare among Sunday intervals. So we can hardly expect it to be the most common Easter interval. In fact, it comes tenth in the order of frequency. It seems that our naive probability pattern was wrong in every detail.

If we deal with intervals that are long enough, we may include within an interval two or more of the century common years (CC, for short). For each added CC included we may make a new list corresponding to Tables III and IV. So we increase the number of possibilities.

But we must consider limits. In actual experience, we cannot go on up to indefinitely long intervals in the simple Julian system of Table III. We cannot actually have an interval longer than 199 years without running into at least one century common year. So Table III is vacuous beyond the interval length 199. Its longest interval will, in fact, be 196(0123). Similarly, we can not get beyond 299 with Table IV; the last term being, in fact, 298(01). When we deal with intervals which include two century common years, the smallest such interval will have to be at least 101 years long; and the longest can not exceed 399 years. Intervals including three CC have a somewhat wider range. They may be barely over two centuries, and they may stretch almost up to six centuries.

The lower and upper limits for each list, and the number of century points that may be included, are given in Table V. The table can be extended indefinitely.

TABLE V

LIMITS OF INTERVALS

(when the number of CC's is given)

Century Common Years	Lower Limit	Upper Limit	Century Points Included
0	0	199	0, 1
1	1	299	0, 1, 2
2	101	399	1, 2, 3
3	201	599	2, 3, 4, 5
4	401	699	4, 5, 6
5	501	799	5, 6, 7
6	601	999	6, 7, 8, 9

Observing these practical limits, we may carry on, making more and more lists like Tables III and IV. So we can get a complete list of all possible Sunday intervals up to a figure as high as we please. Every interval-length listed is valid, of course, only for the QR's and for the CC's indicated. And many integers, like 36 and 37, can not be found in any list at all. If such can not be Sunday intervals, naturally they can not be Easter intervals either.

We can say some definite things also about the limits of location of the intervals that are listed.

Consider, for example, the average interval, 35 years. Appearing only in Table IV, we know that a 35-year interval must include one of the century common years. Therefore it must begin in a century preceding such a year. Furthermore, it has to begin near the end of its century, to reach far enough to include the point where the extra day, February 29, is left out of the century common year. The initial year of the interval, therefore, must have a year ending (YE, for short) not less than 65, and, of course, not more than 99. Any other interval less than a century, in Table IV, is similarly restricted. And the very short intervals must begin very close to the century's end.

At the other extreme, when we deal with intervals near the long end of any list, we shall have to begin them in the very early years of their centuries, and in the right sort of centuries, at that.

So the initial year of every interval is confined by the list that carries it to certain kinds of centuries; and the interval itself sets limits, a ceiling over, or a floor under, the possible year endings of its initial year. We may call these the vertical limitations, set by the number of CC's included and by the size of the interval itself.

In some cases, the vertical limitations limit a particular interval-length out of existence. For example, carrying backward the pattern of Table IV, we should expect, as a first term, 1(012). Now, the floor under this interval, 1, has to be much higher than the floor under interval 35. The year ending must be at least 99; therefore it can only be 99. But any year whose year number ends with the digits 99 has a quartic remainder 3; and this QR is not among the QR's listed for the interval in 1(012). Therefore it turns out that the interval 1 has really no valid cases. However, it should be listed with the others in Table IV.

The elimination of interval 1 leaves 5 as the shortest Sunday interval Sunday never returns to the same calendar day in less than 5 years.

We have now gotten about all the help we can from the requirement that an Easter return must bring the same calendar day to Sunday again. We go on to other factors which have to be taken into account.

In quick summary of the accepted calendar rules* Easter is reckoned as the first Sunday following the calendar full moon day which falls on or next after March 21. To bring an Easter return on a certain calendar day, that day must be Sunday again, and the Paschal full moon must again be within the week just ahead of that day. We have already considered Sunday. We have yet to study the habits of the calendar full moon; remembering that this is not the astronomical moon, though it keeps fairly close to it, but an artificial moon governed by definite arithmetical rules.

In the process of determining the full moon day by the Gregorian rules, we find at the very beginning a rule that is almost as simple as the familiar 4-year rule for leap years. Within limited periods, as, for instance, between now and the year 2199, all calendar moon days come in repeating cycles of 19 years. So, for example, the first full moon of spring this year is reckoned to be on the same calendar day, March 28, as that of 19 years ago, or as that of 19 or 38 years hence.

Because of this recurrency, it will be much to our advantage to classify all years according to the places they respectively occupy in the 19-year cycle. In classical calendar calculation, every year has long been labelled with a "golden number" (GN, for short), which is defined as 1 more than the remainder left after dividing the number of the year by 19. We accept the help of this very practical device.

The golden number of 1945 is 8. By our calendar rules, we reckon that all years in the present period which have GN 8 begin the year with the moon 16 days old on January 1; that is, in technical language, they have the "epact" 16; and, accordingly, must have the Paschal full moon on March 28. For any other golden number, we would find a different epact, and a different corresponding day for the Paschal full moon.

We can show the corresponding relationships for all the years in this present period by making a table of years and golden numbers and epacts and full moon days. This has been done in Table VI.

If you look at the last few rows in Table VI, you might get the impression that there is undue crowding. One of the epact numbers seems to have been crowded out entirely; and it looks as if the last two golden numbers listed should have been dropped down one space, to carry out the pattern formed by those above.

To explain these aberrations, it may be enough to say that the point between April 17 and April 18 happens to be one of the places at which a wrinkle develops in the Gregorian calendar as a result of fitting a 30-day month into its (alternative) 29-day period. By convention, whatever golden number happens to fall into the hole between April

*For thorough expositions of the conditions determining Easter, see "Uncommon Easter Dates" by Alexander Pogo, POPULAR ASTRONOMY, Vol. LI, No. 5, May, 1943; and "Easter Reckoning Made Easy" by George W. Walker, *ibid.*, Vol. LII, No. 4, April, 1944.

17 and April 18 (GN 17 in this case) is shoved one way or the other according to whether the number is between 1 and 11 inclusive or between 12 and 19.

TABLE VI

CALENDAR DAYS FOR PASCHAL FULL MOONS

Moon	Day	Ep.	GN	Sample years
March	21	23		
	22	22	14	1913, 1932, ..., 2198
	23	21	3	1902, 1921, ..., 2187
	24	20		
	25	19	11	1910, 1929, ..., 2195
	26	18		
	27	17	19	1918, 1937, ..., 2184
	28	16	8	1907, 1926, ..., 2192
	29	15		
	30	14	16	1915, 1934, ..., 2181
	31	13	5	1904, 1923, ..., 2189
April	1	12		
	2	11	13	1912, 1931, ..., 2197
	3	10	2	1901, 1920, ..., 2186
	4	9		
	5	8	10	1909, 1928, ..., 2194
	6	7		
	7	6	18	1917, 1936, ..., 2183
	8	5	7	1906, 1925, ..., 2191
	9	4		
	10	3	15	1914, 1933, ..., 2199
	11	2	4	1903, 1922, ..., 2188
	12	1		
	13	*	12	1911, 1930, ..., 2196
	14	29	1	1900, 1919, ..., 2185
	15	28		
	16	27	9	1908, 1927, ..., 2193
	17	25	17	1916, 1935, ..., 2182
	18	24	6	1905, 1924, ..., 2190

Table VI is really, of course, a monthly cycle, rather than a straight list of figures. Its inner structure and relationships come out much more clearly in cyclical form. Even the anomalous crowding between April 17 and April 18 can be smoothed out very simply by taking 30 units for the full cycle instead of 29.

Figure 1 is Table VI in cyclical form. The circle of golden numbers, now evenly spaced, appears as the inner circle. The epact numbers are put in next; and the corresponding days for the Paschal full moon form the petals in the outer ring. For our present purpose, we can ignore the epact numbers and go directly from any golden number to the corresponding day for the first full moon of spring.

The make up of Figure 1 is easy to understand if we recall that the solar year and the lunar month are incommensurable. When we go through a complete solar year, we always have part of a lunar month left over. So, if any given point in the lunar cycle, full moon, for instance, comes on a certain day in one year, that same phase of the moon will be found about 19 days later, or 11 days earlier, in the next year.

For example, the change from 1945 to 1946, that is, from GN 8 to GN 9, shifts the full moon day around the cycle from March 28 to April 16, a net advance of 19 units clockwise in Figure 1. We find the same net angular advance when we go from 1946 to 1947, that is, from GN 9 to GN 10, thanks to the smoothing out of the wrinkle, and the joining of the two ends of Table VI into a circle in Figure 1. In fact, we find that every time we add 1 to the golden number we

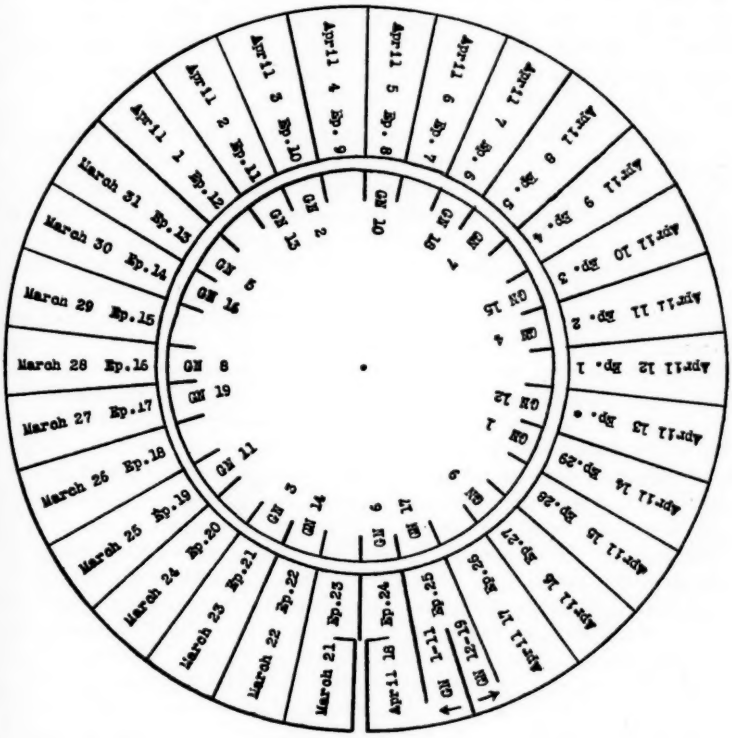

FIGURE 1

THE CYCLE OF GOLDEN NUMBERS, EPACTS, AND FULL MOON DAYS

swing the full moon day around the cycle exactly 19 units, clockwise, until we come to the change from GN 19 to GN 1. At that point, the angular shift is made just one unit less, clockwise, in order to bring us back exactly to the starting-point.

We can as easily compute the angular shift for two years together. If the interval is 2, the golden number is also increased by 2. The angular advance must be, therefore, twice 19 units, clockwise, for any

change that does not go past the point GN = 19, and one unit less for any change that passes that point. It is natural to drop out of the total of 38 or 37 units the completed circuit of 30 units, and say that the net angular advance, when the golden number is increased by 2, is 8 units clockwise if the shift does not go past GN = 19, and 7 units clockwise if it does.

By carrying on, we can compute the net angular advance (AA, for short) corresponding to any amount of increase in the golden number, from 0 to 18. We multiply the amount of the GN increase by 19, drop out as many 30's as can be spared, and we get the net angular advance for the normal case. If the change carries us past the point GN = 19, we diminish the previous answer by 1.

Whenever we start from a particular year and add a given interval, we arrive, of course, at a different terminal year (unless the interval is 0). Whether we arrive at a different golden number or not will depend on the interval added. Every interval is associated with a definite amount of increase in the golden number, or, more accurately, a definite shift around the golden number cycle from 1 through 19 to 1 again. Multiples of 19 make no shift in golden numbers. Any shift different from zero will be due to whatever is left of the interval after taking out all possible 19's. So the golden number shift (GS, for short) may be defined as the remainder left after dividing the interval length by 19.

From each interval, we can thus compute its golden number shift, and can then reckon the corresponding advance in the full moon day (AA) as directed above.

Because of the evident importance of the golden number shift, we will want to group together all intervals having the same GS. Of course, we might do this by writing out all the integers in order in a 19-year cycle. However, we might better make use of the results of our previous work on valid Sunday intervals and include in our survey now only the integers that have passed our first test. So we may take the intervals listed in Tables III and IV, and others that would appear in other similar tables, and do our classifying on them. While we are doing this, we may as well put all these lists together into one table. The result will then be a complete survey of all possible Sunday intervals, classified in accordance with their respective golden number shifts.

The combined table is shown, in part, in Table VII, which may be extended by any one who cares to do so, both to the right, to include all 19 columns, and indefinitely downward to intervals as long as you please.

TABLE VII

ALL VALID SUNDAY INTERVALS
(classified by CC's and by GS's)

CC \ GS =	0	1	2	3	4	5	...
0	0(0123) 95(123) 190(23)	39(123) 134(23) 191(0)	78(23) 135(0) 173(3)	22(23) 79(0) 117(3) 174(01)	23(0) 61(3) 118(01)	5(3) 62(01) 157(012)	...
1	57(012) 152(0123) 247(123)	1(012) 96(0123) 191(123)	40(0123) 135(123) 230(23) 287(0)	79(123) 174(23) 231(0) 269(3)	23(123) 118(23) 175(0) 213(3) 270(01)	62(23) 119(0) 157(3) 214(01)	...
2	114(01) 209(012) 304(0123) 399(123)	153(012) 248(0123) 343(123)	192(0123) 287(123) 382(23)	136(0123) 231(123) 326(23) 383(0)	175(123) 270(23) 327(0) 365(3)	119(123) 214(23) 271(0) 309(3) 366(01)	...
3	209(3) 266(01) 361(012) 456(0123) 551(123)	210(01) 305(012) 400(0123) 495(123) 590(23)	249(012) 344(0123) 439(123) 534(23) 591(0)	288(0123) 383(123) 478(23) 535(0) 573(3)	232(0123) 327(123) 422(23) 479(0) 517(3) 574(01)	271(123) 366(23) 423(0) 461(3) 518(01)	...
...	...	...	...	...	...	...	...

We might pause to admire the structural pattern of Table VII. Every unit in the table includes a fragment of a diamond chain. If, for instance, we take the set of intervals shown in the second column and the fourth row (GS = 1, CC = 3), and extend the pattern a little in both directions, we have the figure shown in Table VIII.

TABLE VIII

DIAMOND PATTERN

Int.	QR
115	0
210	01
305	012
400	0123
495	123
590	23
685	3

The diamond pattern of the quartic remainders is obvious; and we note that the constant difference between the intervals is 95. In many cases, there will be part of a second diamond pattern also within the same unit in Table VII. Each term would differ from the corresponding term of the preceding or following diamond by a constant difference of 532 ($= 19 \times 4 \times 7$). Thus each diamond must link with the diamond before or the diamond after by an overlapping of 38.

Other similar numerical relationships can easily be found between columns or between rows of units in Table VII, by means of which all the remaining units of the table can be readily filled in.

But we should stop admiring Table VII, and get back to Figure 1 for more information about full moon days.

For any given calendar day for Easter, we can easily count off the possible days for the Paschal full moon. They have to be within the week preceding Easter day, and, at the same time, they have to be within the first month of spring, that is, between March 21 and April 18, inclusive. We can read off the span by inspection, in Figure 1.

Figure 1 will also tell us how many angular units, or epacts, are found within the week permitted for full moon days. In many cases, as for Easter on April 1, we find all seven days of the week preceding Easter among the petals of Figure 1, and one angular unit, or epact, for each of the seven days. So, for such Easter days, the total span of the permitted week is 7 epacts, or 7 angular units, in all.

If we want Easter on March 25, a week earlier than Easter this year, we shall not have as many permitted days. We find only 4 of the days preceding March 25 among the petals of Figure 1; and the total span is 4 angular units. So March 25 may be called a 4-epact Easter day.

When we look up Easter on April 19, we find things much more favorable. Thanks to the extra space from the smoothed-out wrinkle, we find a total of 8 angular units within the week preceding April 19. So April 19 is an 8-epact Easter day.

Most of the other cases have integers ranging between 7 and 1, inclusive.

There are just two peculiar cases. Easter on April 18 has a range of 7 epacts if the golden number of the initial year is not more than 11, and it has a range of 8 epacts for the larger golden numbers. We may say that its real range is between 7 and 8 epacts, namely, 7 8/19. The other peculiar case is Easter on April 25, which has a range of 2 epacts if the initial year has a low golden number, and only 1 epact if the GN is greater than 11. We may call April 25 a 1 11/19-epact Easter day.

We get even more specific information from Figure 1. If we look at the sector of epacts included in the span for April 1, for instance, we can see, at a glance, that the requisite condition for bringing the full moon within this week, for any year within the present period, is that the golden number of the year must be one of the five GN's, 5, 8, 11, 16, and 19. This same information appears, of course, in Table VI.

If we start from any year having Easter on April 1, and add a valid Sunday interval which does not change the golden number, keeping within the present period, we must necessarily arrive at another year which has Easter on April 1. All such intervals are to be found in the first column of Table VII.

If we start from any such year, and add a valid Sunday interval which has GS 1, or one that has GS 2, that is, an interval from the second or from the third column of Table VII, we should know by inspection that we can never bring about an Easter return within the present period, for there is no way by which we can increase by 1 or

by 2 one of the GN's in the permitted list, 5, 8, 11, 16, and 19, to arrive at another from the same list. So the intervals in the second and third columns of Table VII can be of no present use to us at all.

On the other hand, we can see a number of ways by which we might increase one of the given golden numbers by 3 to get another on the approved list. So we should expect good results from the intervals in the fourth column of Table VII, for which the golden number shift is 3.

In general, any integral within the present period which has GS 0 makes no change in the position of the full moon day, and should be favorable. An interval which has GS 1 always moves the full moon day around the circuit 19 (or 18) units, which always carries it far beyond the limits of the permitted week, no matter where the starting-point may be. An interval which has GS 2 advances the full moon day 8 or 7 units. There may be cases where this is barely included within the same week as the starting-point. An interval which has GS 3 results in an angular advance of 27 or 26 units clockwise, that is, 3 or 4 units counterclockwise; so there should be plenty of chances of finding both initial and terminal points within a single week. The intervals listed in the fourth column of Table VII should be generally fruitful.

We are beginning to realize that certain of the columns in Table VII, certain of the 19 possible golden number shifts, are definitely favorable, while others are marginal cases, or hopelessly bad, for Easter intervals. The thing that makes the difference is, of course, the angular distance between the initial and terminal points for the full moon day. Any GS that causes a slight displacement, in either direction, is fruitful; any GS that swings the full moon day clear around to the far side of the circle is hopelessly bad.

TABLE IX

GOLDEN NUMBER SHIFTS AND CORRESPONDING NET ANGULAR ADVANCES

AA	GN	GS	AA	GN	GS	AA	GN	GS
..	.....	..	—3	1-16	3	4	1-3	16
—8	1-2	..	—3	17-19	..	4	4-14	..
—8	3-19	17	—2	1-8	..	4	15-19	..
—7	1-2	17	—2	9-19	11	5	1-14	5
—7	3-13	..	—1	1-8	11	5	15-19	..
—7	14-19	6	—1	9-19	..	6	1-6	..
—6	1-13	6	0	1-19	0	6	7-19	13
—6	14-19	..	1	1-11	..	7	1-6	13
—5	1-5	..	1	12-19	8	7	7-17	..
—5	6-19	14	2	1-11	8	7	18-19	2
—4	1-5	14	2	12-19	..	8	1-17	2
—4	6-16	..	3	1-3	..	8	18-19	..
—4	17-19	3	3	4-19	16	..	.....	..

If every golden number shift were associated with a definite net angular advance, it would be very simple to make a list of GS's in the order of their relative fruitfulness for Easter intervals. However, we recall that most GS's may have one or another angular advance accord-

ing to the particular golden number from which the interval starts. It is still possible to make a table of golden number shifts in the order of their associated net angular advances by taking the golden numbers also into account. This has been done in Table IX. For the net angular advances, it will be most convenient to read down; for the golden number shifts, read up. We have carried out the table only a reasonable distance on either side of the most favorable point, AA = 0. It seems quite safe to ignore the cases in which the net angular advance covers a span of much over a week.

To bring out the utility of Table IX, let us see how it may set limits for a particular interval.

Suppose we consider, again, the average Easter interval, 35 years, and let us think of Easters on April 1, or on any other particular calendar day that has just 7 epacts within its permitted week for the full moon day. We want to find out how Table IX can help us in locating the starting-points for 35-year intervals.

The first step is to determine the golden number shift for interval 35. The remainder, after dividing 35 by 19, is 16. Consulting Table IX, we find that the effect of any interval with GS 16 is to swing the full moon day through an angle of 4 units clockwise if the initial year has the golden number 1 or 2 or 3, or through 3 units clockwise if the GN is greater than 3.

It is clear, then, that the full moon day of the initial year must be within the first 3 or 4 days of the permitted week; for, if it comes any later, the full moon day of the terminal year would swing too far ahead to be included in that same week. Table IX puts this limit on 35-year intervals: it requires the full moon day of the initial year to be on the Sunday or Monday or Tuesday preceding Easter, or on the Wednesday preceding provided the golden number of the year is greater than 3.

These may be called the horizontal limits for interval 35, for a 7-epact Easter day, or, specifically, for Easter on April 1. These are to be superimposed on the vertical limits previously found, which confine the initial year of a 35-year interval to the upper third of a century preceding a century common year. Having such definite limits, we should know just where to look for years that might qualify as initial years for 35-year intervals. But more about this later.

If, instead of the 35-year interval, which has the golden number shift 16, we had chosen an interval with GS 13, we should have found the horizontal limits much more cramping. Table IX tells us that with GS 13, the full moon day of the initial year can be no later than the Sunday preceding Easter day, or, more accurately, no later than the seventh epact preceding; and, besides, within that epact, the golden number of the year has to be 7 or more.

An interval with GS 8 gives us a wider range, almost up to Easter day itself; and, of course, an interval with GS 0 may have the full moon of the initial year anywhere within the whole permitted week.

On the other side of the zero point, we find, quite similarly, increasingly stringent limits as we move away from the zero point; which, this time, confine the full moon day of the initial year to the very end of the week preceding Easter.

We can express this information pictorially.

If we imagine the week permitted for full moon days spread out, beginning with the Sunday ahead of Easter, and if, with each day of the week, or, rather, with each included epact, we write out the set of golden numbers in reverse order, from 19 down to 1, we can find a definite cut-point somewhere along the line which, for any given golden number shift, will divide the valid cases from the invalid.

For interval 35, that is, for GS 16, the dividing point is between GN 3 and GN 4 on Wednesday, or in the fourth epact preceding Easter day. All cases to the left of that point are valid; all cases to the right are invalid, because the angular advance, starting from any point to the right of the dividing line, will carry the full moon day too far, beyond the limits of the permitted week.

Table X (A) shows, in rough approximation, the cut points for all the GS's that confine the full moon day of the initial year to the early part of the permitted week. Table X (B) shows similarly the cut-points for the GS's on the other side of the middle point of Table IX. These GS's confine the full moon day to the latter part of the week. You will notice that the cut-points in either series are evenly spaced, each one at a distance of 1 11/19 epacts from the one before.

TABLE X

LIMITS FOR FULL MOON DAY SET BY VARIOUS GOLDEN NUMER SHIFTS
(for Easter on April 1)

	(GS 13)→ 7 |	(GS 5)→ 15 |	(GS 16)→ 4 |	(GS 8)→ 12 |		(GS 0)→ 1 |
(A)	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
	March 25	March 26	March 27	March 28	March 29	March 30	March 31
	Epact 19	Epact 18	Epact 17	Epact 16	Epact 15	Epact 14	Epact 13
	| ←(GS 0) 19	| ←(GS 11) 8	| ←(GS 3) 16		| ←(GS 14) 5	| ←(GS 6) 13	
(B)	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
	March 25	March 26	March 27	March 28	March 29	March 30	March 31
	Epact 19	Epact 18	Epact 17	Epact 16	Epact 15	Epact 14	Epact 13

In the seven epacts of Table X we have, of course, a sector of the 30-epact cycle shown in Figure 1; and we have found it convenient to arrange the 19 possible cases for each epact as subdivisions of the epact length. This should be carried out, then, by marking off 19 subdivisions within each of the 30 angular units of Figure 1. We may say that the whole cycle is divided into 30 epacts, and each epact into 19 "degrees," making a total of 570 of these "degrees" in all.

Incidentally, this subdivision of the epacts takes care nicely of the peculiar epact numbered 25 (see Figure 1). We see now a definite division point within this epact, with a measurable sector on either side.

Counting clockwise, the first 8 "degrees" of this epact, with golden numbers from 19 down to 12, are assigned to April 17; the remaining 11 "degrees" go with April 18.

When we so understand the separation of golden numbers within epact 25, we have the complete explanation of the "peculiar cases" of Easter on April 18 and Easter on April 25. Simple measuring shows us now that the permitted period for the one includes 7 8/19 epacts, and for the other 1 11/19 epacts. This understanding also tells us where to take the end points if we want to make diagrams like those in Table X to give us information concerning Easter on April 18 or 25.

By this device we also do away with the complexities of Table IX entirely. The net angular advance for GS 16, for instance, is no longer sometimes 3 epacts and sometimes 4, depending on the golden number, but, instead, is always exactly 60 "degrees."

The distance between any two adjacent cut-points is 30 "degrees," which is just what we should expect, since the 19 possible GS's must be spread out to cover the whole circle as evenly as possible. $19 \times 30 = 30 \times 19 = 570$.

To get the information shown in Tables X (A) and X (B) pictured properly, we should express the combined series of cut-points, as well as the cycle of epacts, in cyclical form. We can make a disc, as big as the central circle of Figure 1, and space the several cut-points around it in their proper order. The new disc must be free to turn, to enable us to bring its zero point into correspondence with each of the end-points, in turn, of whatever sector of the cycle of epacts may be included within the permitted week for the full moon day.

Such a disc is shown in Figure 2. It is shown here against a sector of the outer rim of Figure 1, in the position which has been diagramed in Table X (A). The rest of the petals can be filled in, from Figure 1; or the inner circle of Figure 2 can be cut out and placed on top of Figure 1, with centers coinciding, and a pin through the centers for the new disc to turn on.

For ease in reading, the "degrees" are not marked, in Figure 2. If they were, one might notice that the first golden number clockwise from any of the cut-points, with the disc in the position shown, would be that number which, when added to the GS, makes 19. This is true whenever the zero point is matched with any boundary line between epacts. (See how Table X (B) bears this out.) When the zero point is matched with the peculiar boundary line inside epact 25, for Easter on April 18 or 25, the golden number on the clockwise side of any cut-point would be this same complement with respect to 19, plus 11 or minus 8.

Figure 2, with the petals filled in, and the inner disc movable, can be used to give the exact horizontal limits for all the valid intervals for Easters on any given calendar day. For intervals within the present period, or within any similar period, first note the limits of the week preceding Easter, on the outer circle. Then set the zero point of the

disc opposite one end of this sector. Read off all the GS's whose cut-points are found within the permitted week, and, for each one, list the cases between the cut-point and the far end of the sector. Then set the zero point opposite the other end of the sector, and repeat, in the opposite direction.

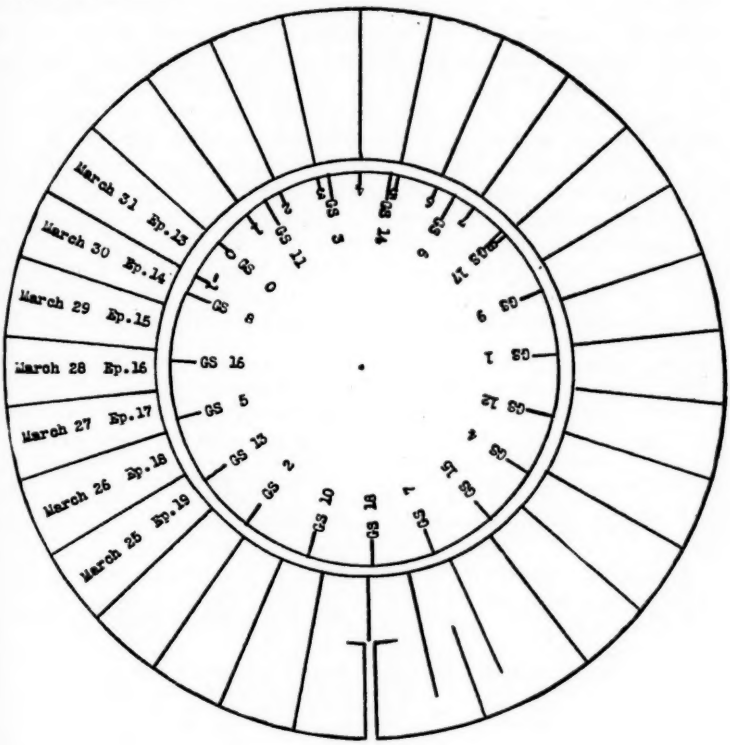

FIGURE 2
THE CYCLE OF GOLDEN NUMBER SHIFTS

If we are interested in a particular interval-length, first compute its golden number shift, then try the two positions of the disc described above, and see if either will bring the cut-point for that GS within the permitted sector. If either position succeeds, read off the list of valid cases as before.

So, for example, to find what cases are possible for interval 35 for Easter on April 1, set the disc as shown in Figure 2, and read, for GS 16, that the valid cases include golden numbers 4 to 19, inclusive, with epact 16, and all the GN's with epacts 17, 18, and 19. So Figure 2 tells

us just what Table X (A) told us before. To be sure, it is just Table X (A) dressed up in curves, so it should tell us the same thing.

We find when we carry out this procedure for an Easter day that has only a few permitted epacts that the choice of GS's becomes quite limited.

For instance, if we want Easter on March 24, the only possible days for the full moon, within the first month of spring, are March 21, 22, and 23, the three epacts being those numbered 23, 22, and 21. Setting the disc shown in Figure 2 with its zero point first at one end of the 3-epact sector, then at the other, we find that the only cut-points that can be brought within the permitted sector are those for GS's 0, 11, and 8. This excludes, therefore, all intervals for Easter on March 24 except those in three of the columns of Table VII.

We keep finding that certain GS's are much more fruitful than others. All things considered, the most fruitful GS's are, in the order of their fruitfulness, 0, 11, and 8, 3 and 16, 14 and 5, and so forth (see Table IX). By the time we get to 17 and 2, we can expect the actual cases of Easter intervals to be very rare, if, indeed, they can be found at all.

TABLE XI

ALL POSSIBLE SUNDAY INTERVALS

(arranged in order of their associated angular advances)

		AA −60°	AA −30°	AA 0°	AA 30°	AA 60°	
	...	GS 3	GS 11	GS 0	GS 8	GS 16	...
CC 0	...	22(23)	11(123)	0(0123)	84(0123)	73(012)	...
		79(0)	106(23)	95(123)	179(123)	168(0123)	
		117(3)	163(0)	190(23)			
		174(01)					
CC 1	...	79(123)	68(0123)	57(012)	46(01)	35(0)	...
		174(23)	163(123)	152(0123)	141(012)	73(3)	
		231(0)	258(23)	247(123)	236(0123)	130(01)	
		269(3)				225(012)	
CC 2	...	136(0123)	125(012)	114(01)	103(0)	130(23)	...
		231(123)	220(0123)	209(012)	141(3)	187(0)	
		326(23)	315(123)	304(0123)	198(01)	225(3)	
		383(0)		399(123)	293(012)	282(01)	
					388(0123)	377(012)	
CC 3	...	288(0123)	277(012)	209(3)	255(0)	282(23)	...
		383(123)	372(0123)	266(01)	293(3)	339(0)	
		478(23)	467(123)	361(012)	350(01)	377(3)	
		535(0)	562(23)	456(0123)	445(012)	434(01)	
		573(3)		551(123)	540(0123)	529(012)	
...	...	...	...	...	...	...	...

This discovery suggests that it would be desirable to doctor up our table of valid Sunday intervals once more, rearranging the columns of Table VII in the order of their respective net angular advances. We should give the column which has GS = 0, which also has AA = 0, the place of honor in the center, and gather around it in order such other columns as give any promise of fruitfulness. To the right of

the central column we should have, in the order of increasing net angular advances, the columns which have GS, respectively, 8, 16, 5, 13, and 2; while on the other side we should have, in order, (counting from GS 0), the columns which have GS, respectively, 11, 3, 14, 6, and 17. This rearranging of Table VII has been carried out, in part, in Table XI. By means of numerical relationships which can easily be found between adjacent columns and between successive rows of units the table may be extended as far as any one may care to carry it out, both to the left and right, and downward to larger intervals.

(To be continued)

The Planets in May, 1945

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern War Time subtract 4 hours, Central War Time, 5 hours, etc. The phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac.*

Sun. The sun will move eastward from $\alpha = 2^h\ 31^m$ to $\alpha = 4^h\ 30^m$, and northward from $\delta = +14°\ 54'$ to $\delta = +21°\ 50'$ during this period. Its path will extend from Aries into Taurus, and the sun will pass a few degrees south of the Pleiades about the middle of the month.

Moon. The phases of the moon will occur as follows:

	d	h
Last Quarter	May 5	6
New Moon	11	20
First Quarter	18	22
Full Moon	27	2

It will be nearest the earth on May 11 and farthest from the earth on May 23.

Mercury. Mercury, as a result of retrograde motion during most of April, will be quite far west of the sun at the beginning of May. It will be at a point of greatest elongation west on May 11. On and near this date it will be on the horizon, a few degrees south of the sunrise point, just before sunrise. At this time it will be nearly on the line between the fourth magnitude stars, α and o Piscium. On May 22, Mercury will reach its greatest heliocentric latitude south.

Venus. Venus will lag behind the sun in its eastward motion during this month. This means that it will be a bright morning star, rising earlier day after day. It will attain greatest brilliancy on May 21. Its stellar magnitude at this time will be —4.2. There will not be any bright star near it at this time, so its brilliancy will be unrivalled.

Mars. Mars will be following the sun eastward but, moving slightly more slowly than the sun, will gradually be moving away from the sun. Like Venus, it will be a morning star. On May 3, it will be very near the vernal equinox point. It will be approaching the earth during this period. Its stellar magnitude will be 1.2.

Jupiter. Jupiter will continue a slow retrograde motion until the middle of the month, after which it will begin a slow eastward motion. Its position on the

average being about eight hours east of the sun makes it a favorable object for observation throughout this period. It will be in the constellation Leo.

Saturn. Saturn will still be visible in the western sky after sunset during this month. Its northern declination of more than 22° is favorable for northern observers. The rings of Saturn are in such a position that the visible surface of the rings at present is the southern one.

Uranus. Uranus will be so close to conjunction with the sun as to be unfavorably situated for observation. Actual conjunction in right ascension will occur on June 4.

Neptune. Neptune, being on the average about nine hours east of the sun, will be visible throughout most of the night during May. It will be in Virgo very near the equator.

Pluto. The position of Pluto, as given by the Nautical Almanac office, for May 1 is $\alpha = 8^h\ 48^m.4$, $\delta = +24°\ 03'$.

Occultation Predictions for May, 1945

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

			IMMERSION				EMERSION			
Date 1945	Star	Mag.	Greenwich C.T.	*a*	*b*	Angle E from N	Greenwich C.T.	*a*	*b*	Angle E from N
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
May 7	290 B.Aqar	6.4	9 15.3	−0.8	+2.1	39	10 16.0	−1.4	+1.0	275
8	24 B.Ceti	6.0	9 37.6	−0.6	+1.9	51	10 40.8	−1.1	+1.4	257
17	η Canc	5.5	3 3.7	−0.3	−1.2	82	3 55.6	+0.4	−1.8	310
21	ν Virg	4.2	0 30.2	−2.7	+0.5	83	1 36.5	−0.7	−2.9	343
29	1 Sgtr	5.1	4 0.4	−0.6	−0.5	145	4 58.5	−2.3	+1.6	238
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
May 2	117 B.Sgtr	5.8	11 26.7	−1.2	+1.7	27	12 9.3	−2.7	−3.2	327
7	290 B.Aqar	6.4	8 58.0	−0.4	+2.0	46	9 53.7	−0.7	+1.2	276
17	η Canc	5.5	2 58.8	−0.6	−1.7	110	4 2.1	−0.2	−1.6	286
20	ν Virg	4.2	23 50.7	−1.6	−0.2	117	1 17.6	−1.8	−1.2	306
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
May 2	117 B.Sgtr	5.8	10 9.0	−2.7	+2.3	49	11 9.3	−1.8	−1.5	324
2	26 Sgtr	6.1	12 17.7	−2.4	−0.8	114	13 39.4	−1.8	0.0	243
3	53 Sgtr	6.2	13 26.4	−2.6	−1.1	117	14 36.1	−1.3	+0.7	222
3	274 B.Sgtr	6.1	13 39.5	−2.7	−1.3	120	14 44.8	−1.1	+0.9	218
5	128 B.Capr	6.5	11 32.7	−1.3	−0.2	127	12 22.5	−1.7	+2.7	206
14	BD+21°918	6.3	4 46.6	..	..	3	4 48.9	..	..	0
15	Saturn	0.3	3 21.1	−1.2	−0.1	60	4 11.5	+0.2	−2.3	313
17	η Canc	5.5	2 52.6	..	..	168	3 32.8	−2.9	+1.5	230
17	39 Canc	6.5	6 31.9	+0.1	−1.8	123	7 25.4	+0.2	−1.1	271
17	40 Canc	6.5	6 36.3	+0.2	−1.9	130	7 27.5	+0.1	−0.9	264

OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′*

May 2	117	B.Sgtr	5.8	10	59.1	—2.6	+1.2	53	12	15.9	—2.6	—1.9	303
2	26	Sgtr	6.1	13	33.2	..	..	161	13	49.2	..	..	184
15	Saturn		0.3	3	39.5	—0.7	+0.6	45	4	22.9	+0.7	—1.8	333
16	BD+22°1735		6.9	3	55.0	—1.0	+0.5	50	..	..	..	..	...
17	BD+21°1844		7.0	0	04.3	—2.9	+0.6	74	..	..	..	..	...
17	η	Canc	5.5	3	17.0	—0.1	—2.7	146	4	10.2	—0.9	—0.5	253
18	BD+18°2182m		7.1	1	52.0	—1.8	—1.7	115	..	..	..	..	...
18	BD+18°2207		7.5	5	00.5	—0.5	—1.3	100	..	..	..	..	...
20	291	B.Leon	7.3	5	23.8	—1.9	—0.3	70	..	..	..	..	...
20**	ν	Virg	5.7	23	54.2	—1.0	—2.9	162	1	03.1	—3.2	+1.1	262
24	BD—6°3911		7.0	0	06.9	..	..	50	..	..	..	..	...

*Computation by George R. Schaefer and Paul Herget, communicated by Commodore J. F. Hellweg, Superintendent U.S. Naval Observatory.

**Emersion on the following day.

Asteroid Notes

By HUGH S. RICE

JUNO. The rather close approach (0°3) to α Orionis was seen here on February 18, but did not appear very close in the telescopic field. It was a typical instance where closest approach does not correspond in time to the conjunction, the asteroid's motion being toward the northeast. We last saw Juno some days later still in Orion, with diminishing brightness, and it is now becoming too faint for small telescopes. In fact, toward the last the magnitude seemed to decrease more than was expected. On January 20 it passed by a curious formation of stars about half-way between α and ζ Orionis, the configuration being a question-mark reproduced backwards.

We have also been observing the following four minor planets on almost every clear night; often all four would be picked up, one after another.

IRIS is at its western stationary point after April 15, east of Sextans. The magnitude then is about 10 and hence faint for a small glass, and will soon be difficult for 4-inch or larger instruments.

PALLAS is a fine object now. When observed near η Virginis, it was practically in the field with Neptune, which latter planet has been retrograding for several weeks between δ and η Virginis. Various additional celestial objects like this may be seen during the course of asteroid hunting, and enhance the pleasure of observing. In mid-April PALLAS is east of β Leonis near its turning-point, at about magnitude 8.

VESTA, which never fails to provide good observing, is east of Pallas in Virgo. On March 20 it was to have been nearly in coincidence with 78 Virginis, but just on the critical day we missed the phenomenon because of cloudy skies. It makes a close approach to σ Virginis near the middle of April. Vesta is brightest in April at about magnitude 6.8.

CERES is still farther east in Virgo and is brightest in April and May, at magnitude about 7.5. We first picked up Ceres in January, when it was so far east that we had to observe about 5 A.M. Finding an asteroid the first time during an apparition is interesting. When found, the position gives a check on the ephemeris. Naturally it takes longer to locate than subsequently, when the surrounding stellar field is familiar. When the field is learned, the work becomes

far easier. (We refer to the telescopic field and not the naked-eye stars.) We found it was easy to pick up Vesta in a very few seconds, with 18x held *in manu*, with no tripod or support, when it was near 78 Virginis.

The following ephemerides are from the Yale U. Observatory.

EPHEMERIDES OF ASTEROIDS, 0^h U.T.

7 IRIS

1945	α h m	δ ° ′	1945	α h m	δ ° ′
Apr. 15	10 38.0	+ 0 10	May 5	10 38.1	+ 1 8
20	10 37.1	0 30	10	10 39.6	1 13
25	10 36.8	0 46	15	10 41.6	1 14
30	10 37.1	+ 0 59	20	10 44.1	+ 1 13

2 PALLAS

1945	α h m	δ ° ′	1945	α h m	δ ° ′
Apr. 15	11 50.2	+15 33	May 5	11 47.4	+18 59
20	11 48.6	16 40	10	11 48.2	19 27
25	11 47.6	17 37	15	11 49.6	19 46
30	11 47.2	+18 23	20	11 51.6	+19 58

4 VESTA

1945	α h m	δ ° ′	1945	α h m	δ ° ′
Apr. 15	13 9.4	+ 6 28	May 5	12 53.9	+ 7 5
20	13 4.9	6 47	10	12 51.4	6 58
25	13 0.8	6 59	15	12 49.6	6 46
30	12 57.1	+ 7 6	20	12 48.5	+ 6 27

1 CERES

1945	α h m	δ ° ′	1945	α h m	δ ° ′
Apr. 15	14 20.9	— 0 3	May 5	14 3.3	+ 0 28
20	14 16.5	+ 0 9	10	13 59.2	0 26
25	14 12.0	0 19	15	13 55.5	0 20
30	14 7.6	+ 0 25	20	13 52.3	+ 0 10

Hayden Planetarium, American Museum of Nat. Hist., New York, March 24, 1945.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

In the following article are printed several solutions of the paths of fireballs. I am particularly glad to be able, for once, to publish quite promptly that of the fine bolide seen in Oregon on 1945 January 7. Due to numerous causes such solutions have, as a rule, to be put off for a very long time. I should like to call the attention of members to the fact that the dues for 1945 should be paid, and that Flower Observatory Reprint No. 65 has been distributed to all members who have done so. It will be sent to others when their dues arrive. This reprint contains all the Meteor Notes for 1944. Reprints are not being sent to our members in the armed forces because it is believed that they will find it impossible to preserve them on active service and, on their return, will wish to keep a complete file. We may add that annual dues are remitted for all those so serving our country during their terms of service.

Fireball of 1934 August 31/32

On this date we have two, and probably three, reports on a fireball that appeared over New England at 7:38 P.M., E.S.T. The reports are S1, G. B. Weston and four others, Paris, Me., $\lambda = 70°\ 29'$ W, $\phi = 44°\ 16'$ N, h (45°±) but 32° used, $a_2 = 125°$, $h_2 = 5°$, angle to vertical 70° to 75°, duration 5 sec., very brilliant, greenish-white, ¼ Moon, train 5 sec., sound—yes! "a rattling roar—attention first attracted by sound." S2, 3rd Officer L. P. Roberts, A. S. S. Evangeline, "2040 (75 meridian time)" $\lambda = 69°\ 43'$, $\phi = 42°\ 35'$ N, . . . meteor . . . falling from directly overhead to . . . $h = 10°$, bearing east magnetic . . . blue-white, brighter than Venus, visible 4 sec., leaving a long reddish trail . . S3, S. P. Young, Ellsworth, Me., 7:38 P.M., E.S.T., $\lambda = 68°\ 26'$ W, $\phi = 44°\ 33'$ N, "appeared in S, possibly a little W of S . . . travelled E, at first moving very rapidly, but seemed to slow down and become more brilliant . . . (at last) moved slowly with great amount of light and threw off . . . particles . . . seemed to burst." If we *assume* S2 was using daylight time, or that he recorded the object one hour late, we have a solution as follows:

Date	1934 August 31/32 7:38 P.M., E.S.T.
Sidereal time at end point	281°
Began over	$\lambda = 68°\ 33'$, $\phi = 42°\ 52'$, at 148 km (S1)
Ended over	$\lambda = 67°\ 57'$, $\phi = 43°\ 01'$ at 27.3 ± 0.5 km
Length of path	128 km
Projected length of path	50 km
Observed velocity	29 km/sec
Radiant (uncorrected)	$a = 74°.5$, $b = 67°$; $\alpha = 254°$, $\delta = +33°$.

No zenith correction is computed nor a corrected radiant as the former is rather small in any case, due to small zenith distance, and the solution must be considered of low weight, as any error in the azimuth from S2 would change the results somewhat, and we further had to *assume* that the object seen at S2 was the same as seen by the others.

Fireballs of 1941 December 10/11

On this date at 8:22 and 8:22½ P.M., E.S.T., two fireballs were seen by two observers each, yet ended quite near together. At first, I was naturally tempted to consider all four observations as belonging to the same object, but study of the reports proved this hypothesis absolutely impossible as, for once, all four observers gave coordinates for both ends of the paths. Satisfactory heights have been worked out for both objects. Taking them in order we condense the reports: S1, ship—, $\lambda = 75°\ 15'$ W, $\phi = 35°\ 10'$ N, 0122 GCT Dec. 11, brilliant, $h_1 = 10°$, $a_1 = 148°$, $h_2 = 10°$, $a_2 = 185°$ . . . white . . . long brilliant yellow trail which seemed to break into pieces before it disappeared . . . meteor remained visible about 10 sec . . . S2, ship—, 0122 GCT . . . $\lambda = 76°\ 29'$, $\phi = 37°\ 14'$, very brilliant . . . long red and yellow tail . . . a_1 in NW, $h = 30°$, max. $h = 50°\pm$, a_2 in NE, $h_2 = 15°$. Its trail which at times extended 50° in azimuth . . . visible 15 sec.

There is only one difficulty: there is nothing to do but use for S2 $a_1 = 135°$ and $a_2 = 225°$. When this is done, the max. h is not 50° but 35°±. Any adjustment would be purely arbitrary as there is nothing to tell whether a_1 or a_2 is more nearly correct. As the radiant is so far from the apex, the zenith correction is very large, throwing the corrected radiant below the horizon. The data follow:

Date	1941 Dec. 10/11 0822 P.M., E.S.T.
Sidereal time at end point	25°
Began over	$\lambda = 77°\ 32'$, $\phi = 38°\ 03'$ at 76.6 ± 1.4 km
Ended over	$\lambda = 74°\ 53'$, $\phi = 38°\ 29'$ at 66.5 ± 9.7 km
Length of path	236 km
Projected length of path	236 km
Observed velocity	19 km/sec
Radiant (uncorrected)	$a = 77.5$, $h = 1°.4$; $\alpha = 304°$, $\delta = -9°$
Zenith correction (parabolic)	—12°.7
Radiant (corrected)	$a = 77°.5$, $h = -10°.8$; $\alpha = 297°$, $\delta = -17°$

For the second object we have: S1, Wm. F. Wallis, Washington, D. C., $\lambda = 77°\ 04'$, $\phi = 38°\ 55'$ . . . brilliant meteor at 8:25 P.M., E.S.T., due E . . . appeared N of Orion, traveling in line $\alpha\gamma$ Orionis, direction down and to left . . . appeared about 10° from α . . . traveled about 5° without exploding, leaving a bright yellowish trail which vanished almost immediately. Plotting these data on map IX we find $\alpha_1 = 95°.2$, $\delta_1 = +8°.4$, $\alpha_2 = 100°$, $\delta_2 = 9°.2$, and calculate $a_1 = 274°.5$, $h_1 = 18°.9$, $a_2 = 270°.2$, $h_2 = 15°.7$. For S2 I have a plotted train on map IX by J. H. Lenzil, Ardmore, Pa. $\lambda = 75°\ 18'$, $\phi = 40°\ 00'$, secured by my colleague, Dr. T. H. Cope. This meteor was reported as first magn., 8:20 P.M., train of sparks, fluctuations in brightness. From his plot I measure $\alpha_1 = 54°.2$, $\delta_1 = -26°.9$, $\alpha_2 = 62°.5$, $\delta_2 = -20°.9$, and calculate $a_1 = 332°.3$, $h_1 = 17°.5$, $a_2 = 332°.7$, $h_2 = 19°.5$. As the radiant from these two paths is nearly at the maximum distance from the apex, the zenith correction is very large. The data follow:

Date	1941 Dec. 10/11 8:22½ P.M., E.S.T.
Sidereal time at end point	26°
Began over	$\lambda = 74°\ 25'$ W, $\phi = 38°\ 51'$ at 79.2 ± 3.8 km
Ended over	$\lambda = 74°\ 10'$, W, $\phi = 38°\ 51'$ at 56.4 ± 2.1 km
Length of path	46 km
Projected length of path	40 km
Radiant (uncorrected)	$a = 52°$, $h = 29°.6$; $\alpha = 342°$, $\delta = -6°$
Zenith correction (parabolic)	—10°.6
Radiant (corrected)	$a = 52°$, $h = 19°$; $\alpha = 336°$, $\delta = -14°$

No fireball is found in the von Niessl-Hoffmeister Catalogue which has a radiant closely resembling that of either of the above fireballs, though No. 480 and No. 486 might be noted.

Fireball of 1943 November 24/25

On this date at 1:52 P.M., E.S.T., a conspicuous fireball was seen from numerous places in western North Carolina. Our efficient regional director, Dr. Milton L. Braun, being informed later that afternoon of its passage, at once began a campaign of personal interviews, letters, and requests in the local papers for reports. Later, he turned over to me all his data with the verdict that not enough had been secured for a solution, due largely to the neglect of observers to send replies containing additional information. For my part, I have plotted the azimuths and concur in his opinion. All we can say is that the object appeared S.W. from Salisbury, N. C., and disappeared between N and N.E. of that place. While in the N.W. quadrant, where most observers saw it, its altitude from Salisbury was 20° at first (five estimates all in fair agreement) and 18° at last (same remark). No one reported it overhead or from the west side of the path, though we have reports from several places west of Salisbury, including Forest Hill ($\lambda = 81°\ 52'$, $\phi = 35°\ 20'$) where the path was entirely to the north and at a low altitude. The object was bluish-white or silver in color and very brilliant. It had a large apparent disk (20'?), moved slowly, and had a path which did not

slope greatly, at least until near the end. It had a short tail three times the diameter of its head in length, which followed immediately. There was no smoke-train reported. This probably means that it did not come very low. An uncertain calculation for the height of a point on its path due N.W. of Salisbury would give 74 ± 16 km. This at least bears out previous remarks. From its general direction of motion it *could not* be a Bielid meteor.

Though no definite path could be computed, the fireball was too bright not to be placed on permanent record. It was no fault of Dr. Braun's that the data were insufficient as he spent much time and trouble on the case. I am greatly indebted to him for his work, since, thanks to him, fireballs which appear over North Carolina have a better chance for having their paths computed than is true for at least 90 per cent of the United States.

Fireball of 1945 January 7/8

On this date at about 8:07 P.M., P.S.T., a fine fireball or bolide started over west-central Oregon and moving SSW ended near the coast. Our efficient regional director, Prof. J. Hugh Pruett, on being informed that the body had appeared, promptly by press, radio, and telephone, and later by numerous letters and questionnaires, gathered some 78 reports. From these he made a preliminary solution for the projected path, but, running into certain difficulties due to a curious distribution of the better observers, he sent the whole, reports and preliminary solution, to me. Examination of these documents convinced me that, by applying our usual methods, a fairly good solution could be obtained and I have pushed this to what is believed to be a satisfactory conclusion.

To reach this I read all the reports and, most carefully, the letters in which Pruett explained to me his impressions of them and what he had done. A start was made by preparing a new map with a projection more suitable for the case, and replotting on this all usable azimuths. As expected, the sub-end point E_1 came out well, and, while the sub-beginning point B_1 is not so clearly fixed, still the azimuth of the projected path is one of the best ever derived here. H_2, the end height, would be even better determined but for the fact that it is not possible to determine whether all the observers used the explosion point as the actual end point E. We have some who have no altitudes but definitely spoke of seeing fragments falling down from the explosion point. It is probable, therefore, that H_2 is actually slightly below the true explosion point but above where the fragments vanished. Nevertheless, I believe that E, as calculated, almost represents the final explosion point. Also the resulting end height H_2, based upon 8 seemingly good reports as to altitude, deserves much confidence. H_1, though based upon less certain data, is believed to be correct within the average error given. Hence the atmospheric path is at least fairly well determined.

The most notable peculiarity is that most of the observers who sent in usable reports, *i.e.*, gave coordinates, were almost in the vertical plane of motion of the fireball and were concentrated north of where it began. This meant that the path was really or almost vertical to many. Fortunately, there were enough to the side near the end of the path to fully determine E_1. B_1 depends upon fewer and less accurate reports from the side. H_1 also suffers from the fact that many of the best reports came from people indoors who saw the end well but of course entirely missed the upper part of the path. The main reason that the azimuths are so well determined is that several observers were trained in the use of instruments and employed them, while others secured help in this matter. These

people of Oregon are to be congratulated on having such an intelligent appreciation of the scientific importance of securing good coordinates for a fireball. In most states it is rare when an observer will use the time and effort to do this.

The object was most generally reported to be bluish-white in color turning more red towards the end. To those within perhaps 100 km of the nearest point of the path, it was 2 to 3 times as bright as Venus; when it burst considerably brighter. It left no long-enduring train, what there was disappeared as soon as the fireball itself. The sound phenomena are limited to reports from six stations, three due north of E near Coos Bay and two due east. At Agness, Ore., due south, a house was jarred. Other stations were too distant for sound effects. Using the six durations which appear on the best reports and refer to the whole period of visibility, we get 2.9 ± 1.3 seconds. As usual, the value means unfortunately little. The data follow:

Date	1945 January 7/8; 8:07 P.M., P.S.T.
Sidereal time at end point	45°.0
Began over	$\lambda = 123° 25'$, $\phi = 43° 38'$ at 146 ± 27.2 km
Ended over	$\lambda = 124° 07'$, $\phi = 42° 42'$ at 40 ± 17.5 km
Length of path	159 km
Projected length of path	118 km
Velocity	55 km/sec (very uncertain)
Radiant (uncorrected)	$a = 208°.5$, $h = 41°.3$; $\alpha = 129°$, $\delta = +69°$
Zenith correction (parabolic)	$-1°.7$
Radiant (corrected)	$a = 208°.5$, $h = 39°.7$; $\alpha = 127°$, $\delta = +68°$

From the height at which the fireball burst it is doubtful if any debris fell as meteorites. An examination of the von Niessl-Hoffmeister Catalogue gives no fireball from this radiant. Most hearty appreciation is due Prof. Pruett for his invaluable help, in every way, which made this solution possible. And also to the numerous persons who took time and trouble to report to him, often filling out questionnaires in addition to their original letters. I regret that lack of space prevents my giving a list of these observers and their stations.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, 1945 February 27.

Contributions of the Society for Research on Meteorites

Edited by **FREDERICK C. LEONARD**
Department of Astronomy, University of California, Los Angeles 24

A Legal Treatise on Meteorites; or, Did You Ever See a "Tomanowas"?*

ROY R. CARPENTER
1903 Elm Street, Denver, Colorado

(Communicated by H. H. Nininger)

*[This article was written in the form of a private letter to Dr. H. H. Nininger of Denver, Colorado, who in turn communicated it to the Editor of the Society for publication in *C.S.R.M.*, where it is being published with the author's permission. In a postscript to the letter, the author writes: "I might have entitled the foregoing 'A Legal Treatise on Meteorites; or, Did you ever see a "Tomanowas"?'. Carrying that last thought in mind, I refer you to p. 2204, Vol. *M* of *Compton's Picture Encyclopedia*, 1931 edition, where there appears

May I preface this by saying that I have no thought that I can add one jot to your knowledge, at least your scientific knowledge, concerning meteorites? To acquire this knowledge I appreciate that you have applied the keen discernment of your own scientific faculties over a period of years; that you have employed the technique of the assayer and the metallurgist; that you have calculated distance, velocity, force, friction, weight, temperature, calling to your aid the tables, scales, units, and means of measurement commonly availed of by the physicist and the mathematician; that you have pursued and dug meteorites from their lairs; that, to know better whence they came, you have traced them back on their pathways with the telescope of the astronomer; that you have dissected the bodies of these "heavenly visitors" with the skill of an anatomist, only to lay down the hammer and saw to view the more minute parts by the aid of the magnifying glass and the microscope; that, as you have trailed their telescopic pathway into the unknown azure of the distant stratosphere, so have you traced them back thru history, religion, legend, and into time whence the mind of man runs not to the contrary; that you have even polished, shellacked, dressed them up, and commercialized them, not only as educational exhibits in museums but as articles of usefulness in the homes of man. Verily, you have given them the acid test, figuratively and in truth! But you know far better of all these things of which I have tried to speak than I. Now, while you have looked upon meteorites from these various aspects, have you ever viewed them thru the "eye" of the law or considered them, may I say, from the viewpoint of the lawyer? No? Then come go with me into court. I venture you never thought of searching there for your so-called "Earth-pelters." But before we go, remember I again emphasize that I am just off on a side trip and I can add, if add I can at all, only to the fringe of your meteoritical profundity.

Not long ago, I had occasion to attend to some legal matters in the courthouse of Bozeman, Montana. On leaving, I noticed, in the corridor, among other exhibits, one labeled a meteorite. This prompted the question as to whether a meteorite had ever had its day in court. Reflecting on the part it had played in superstition, embryonic religion, and now in the science of this more enlightened age, I pondered in a self-questioning attitude something as follows: What part has a meteorite played in law? Is it classed as "treasure trove"? Are finders keepers? Or is it just nature's contribution to the land which gravity saw fit to make its landing place, or, as in some instances where it may have been transported otherwise by nature from the place of its original fall, as the granitic boulders of Laurentian origin now found in the ice-age deposits of the north-central and eastern parts of the United States were transported by nature, is it just an "erratic"? These self-imposed legal queries prompted me to make a careful and quite exhaustive search thru the indexes of standard legal dictionaries, encyclopedias, other recognized legal reference-works, and further, the various court-reporter systems of the United States, to ascertain what, if any,

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the picture of a meteorite, beneath which there is a note to the effect that it fell near Willamette, Oregon, and weighs about 15 tons. From the description in the case of the Oregon Iron Company *v.* Hughes of the 'Tomanowas,' it would appear that the one pictured on this page is the one referred to in that case, and, if so, then you have possibly seen this very 'Tomanowas' in some museum.—R. R. C." The 15¾-ton Willamette, Oregon, siderite, which is by far the largest meteorite yet recovered within the United States, is on permanent exhibition in the Hayden Planetarium of the American Museum of Natural History in New York City.—Ed. *C.S.R.M.*]

meteorite or meteorites may have "fallen into court." May I say, in passing, that I found their recorded visits—*i.e.,* reported cases concerning meteorites—in court to be every bit as rare as you have found recorded falls of meteorites in the houses of man? There are but two officially reported cases of court actions concerning meteorites in our case-reporter systems in the United States. As you may know, our case-reporter systems are confined to cases carried from the courts of general jurisdiction, lower courts, to the higher courts, such as courts of appeal and supreme courts of the various States and the United States. Thus, there may have been other cases decided in some of our lower courts, and, if not appealed, they would not be indexed or appear in our case-reporter systems. But, as sometimes happens, a case in a lower court, tho not appealed, may be of such interest as to prompt some correspondent to contribute to some legal journal an article on such a case. One such case in the United States and two such cases in France concerning meteorites appear in *The Albany Law Journal* and in *The Irish Law Times,* to which I shall refer later, after I have briefed for you the two officially reported cases in the United States. The decisions, as announced in these two cases, may be considered the law as to who is the rightful owner of a meteorite upon its falling to the Earth; and I believe that these two decisions would be followed by the higher courts in all our States. These two cases are of interest, not only from the legal aspect of establishing the general law as to who would be the owner, but also from the fact that the one establishes a recorded fall as to definite time and place, duly verified by witnesses under oath in court, and that this particular meteorite was of the stone type, an aerolite; while the other concerns a meteorite, the time and place of fall of which were unknown and which may in fact have been transported to where it was found by other forces of nature than gravity—its only record being seemingly clouded and lost in the superstition and medical magic of the native Indians thereabout, who believed in the power of the water they found in its "pot-holes," it being evidently the iron type of meteorite, a siderite. I shall adhere quite closely to the text of the court reports of these two decisions, so that you may get not only the reasoning of the lawyers presenting the claims of their litigants and of the courts deciding the issue, but also such side-lights as may be incident to the legal pith coursing the two actions. Some of the text will be quoted verbatim.

The first of these cases is the case of John Goddard *v.* H. V. Winchell, decided October 4, 1892, reported in *86 Iowa Supreme Court Reports,* p. 71; 52 N. W. 1124. The facts in this case, as determined in the trial held in the lower court, are detailed in the following quotation taken from the decision as announced by the justice of the supreme court:

"(1) That the plaintiff, John Goddard, is, and has been, since about 1857, the owner in fee simple of the north half of section No. 3, in township No. 89, range No. 25, in Winnebago County, Iowa, and was such owner at the time of the fall of the meteorite hereinafter referred to. (2) That said land was prairie land, and that the grass privilege for the year 1890 was leased to one James Elickson. (3) And that on the 2nd day of May, 1890, an aerolite passed over northern and northwestern Iowa, and the aerolite, or fragment of the same, in question in this action, weighing, when replevied, and when produced in court on the trial of this cause, about 66 pounds, fell onto the plaintiff's land, described above, and buried itself in the ground to a depth of 3 feet, and became imbedded therein at a point about 20 rods from the section line on the north. (4) That, the day after the aerolite in question fell, it was dug out of the ground with a spade by one

Peter Hoagland, in the presence of the tenant, Elickson; that said Hoagland took it to his house, and claimed to own same, for the reason that he had found same and dug it up. (5) That on May 5, 1890, Hoagland sold the aerolite in suit to the defendant, H. V. Winchell, for $105, and the same was at once taken possession of by said defendant, and that the possession was held by him until same was taken under the writ of replevin herein; that the defendant knew at the time of his purchase that it was an aerolite, and that it fell onto the prairie south of Hoagland's land . . . . . (10) I find the value of said aerolite to be one-hundred and one dollars ($101), as verbally stipulated in open court by the parties to this action; that the same weighs about 66 pounds, is of a black, smoky color on the outside, showing the effects of heat; that it is an aerolite, and fell from the heavens on the 2nd of May, 1890; that a member of Hoagland's family saw the aerolite fall, and directed him to it."

Such may be considered the facts in the case. Now as to the conclusions of the law; the district court, *i.e.,* the court in which the case was originally tried, found that the aerolite became a part of the soil onto which it fell; that the plaintiff was the owner thereof, *i.e.,* the land owner; and that the act of Hoagland in removing it was wrongful. From this decision, the defendant, Winchell, appealed to the supreme court, claiming error on the part of the charge to the jury in the lower court in holding that the aerolite became a part of the soil. At that day, this was a new question for the court to decide, and there is a note with the report of this case to the effect that "there seems to be no authority on the very interesting and novel question presented in this case, except as discussed by this court in its opinion." The appellant's attorney turned back to common law and such precedent as he thought would favor his theory of the case and evoked the language of Blackstone as follows: "Whatever movables are found upon the surface of the Earth, or in the sea, and are unclaimed by any owner, are supposed to be abandoned by the last proprietor, and, as such, are returned into the common stock and mass of things; and, therefore, they belong, as in a state of nature, to the first occupant or finder." But the justice in the supreme court reasoned in effect thus: the term "movables" must not be construed to mean that which can be moved, for, if so, it would include many things that are movable which are known to be realty; it means such things as are not naturally parts of the Earth or sea. If we look to the natural formation of the Earth and sea, it is not difficult to understand what is meant by "movables" within the spirit of the rule cited. To take from the Earth what nature has placed there in its formation, whether at the creation or thru the natural processes of the acquisition and depletion of its particular parts, as we witness it in our daily observations, whether it be the soil proper or some natural deposit, as of mineral or vegetable matter, is to take a part of the Earth and not movables. The subject of this dispute is an aerolite, of about 66 pounds' weight, that "fell from the heavens" onto the land of the plaintiff, and was found 3 feet below the surface. It came to its position in the Earth thru natural causes. It was one of nature's deposits, with nothing in its material composition to make it foreign or unnatural to the soil. It was not a movable thing "on the Earth." It was in the Earth and in a very significant sense immovable; that is, it was movable only as parts of the Earth are made movable by the hand of man. Except for the peculiar manner in which it came, its relation to the soil would be beyond dispute. It was in its substance, as we understand, a stone. It was not of a character to be thought of as "unclaimed by any owner" and, because unclaimed, "supposed

to be abandoned by the last proprietor," as would be the case under the rule the appellant, Winchell, would evoke; in fact, it had none of the characteristics of the property contemplated by that rule.

The general rules of the law, by which the owners of riparian titles are made to lose or gain by the doctrine of accretions, are familiar. Thru the action of the elements, wind and water, the soil of one man is taken away and redeposited in the field of another; and thus, all over the country, we may say, changes are constantly going on. By these natural causes, the owners of the soil are giving and taking, as the wisdom of the controlling forces determine. By these operations, one owner may be affected by a substantial gain and another by a similar loss. These gains are of accretion, and the deposit becomes the property of the owner of the soil onto which it is made. The justice stated further in effect that scientists of nature had said that from 600 to 700 of these stones fall to our Earth annually. If they are, as indicated in argument, departures from other planets, and if, among the planets of the solar system, there is this interchange, upon what principle of reason or authority can we say that a deposit thus made shall not be that class of property that it would be if originally of this planet and in the same situation? If these exchanges have been going on thruout the countless ages of our planetary system, who shall attempt to determine what part of the rocks and formations of a special area took final resting in and upon the Earth, and are of meteoritic acquisition, and a part of that class of property designated in the appellant's argument as "unowned things," to be the property of the fortunate finder, instead of the owner of the soil, if the rule contended for by the appellant is to obtain? So it is not easy to understand why stones or balls of metallic iron, deposited as this one was, should be governed by a different rule from that which obtains for deposits of boulders, stones, and drift upon our prairies by glacial action; and who would contend that these deposits, from floating bodies of ice, belong not to the owner of the soil but to the finder? Their origin or source may be less mysterious, but they too are "tell-tale messengers" from far-off lands and they also have value for historic and scientific investigation. It is said by the appellant, Winchell, that the aerolite is without attachments to the soil and of value only for scientific purposes, but I feel that nothing in the facts of the case will warrant his saying that it was not as well adapted for use by the owner of the soil as any other stone, or, as the appellant is pleased to denominate it, a "ball of metallic iron." True; the rule cited by the appellant, with cases supporting it, indicates that the finder of lost articles, even when they are found on the property of another or in a building of another, is the owner thereof against all the world except the true owner. That rule may be true in some States, but it is not applicable to the case at bar, for the subject of the controversy was never lost or abandoned. Whence it came is not known, but, under the natural law of its government, it became a part of this Earth, and we think it should be treated as such. It is said by the appellant that this case is unique; that no exact precedent can be found and that the conclusion must be based largely upon new considerations. True; no similar question has, to our knowledge, been determined in a court of last resort, but the interest manifested has induced us to give the case careful thought, and our conclusion seems to us to be most nearly analogous to the generally accepted rules of law bearing on kindred questions and to subserve the ends of substantial justice. The judgment of the district court is, therefore, affirmed.

The gist of this decision is expressed in the syllabus of the report:— "An

aerolite which imbeds itself in the Earth, as it falls from the sky, becomes the property of the owner of the land, and another person cannot acquire ownership of it by discovering it, digging it up, and carrying it away."

The second case that I have to present is the case of the Oregon Iron Company *v.* Hughes, decided July 17, 1905, in the Supreme Court of Oregon, reported in *47 Supreme Court Reports,* p. 313; 81 Pacific, 572. This case was appealed from the Circuit Court of Clackamas County, Oregon.

The Oregon Iron Company, the defendant, in 1902, discovered upon the land of the plaintiff, an irregularly shaped mass of iron, with infusion of nickel and a trace of cobalt, weighing several tons, supposed to be of meteoritic origin, and shortly afterwards, without knowledge or consent of the plaintiff, the owner of the land, removed the meteorite to its own premises. The plaintiff, Hughes, upon ascertaining the fact, demanded the property, and, being refused, brought the action to recover it, and obtained judgment. From that judgment, the defendant, the Oregon Iron Company, appealed, contending that the lower court was in error in the matter of law in instructing the jury. The trial court instructed the jury upon the theory or assumption that this mass of iron, or this meteorite, when removed, was real property, *i.e.,* a part of the soil, and belonged to the owner of the soil. Upon this instruction, the jury found in the plaintiff's favor. The appellant, the Oregon Iron Company, contended that the court should have instructed the jury on the theory that the property, this meteorite, had been appropriated, that is, severed from the land and reduced to possession and ownership by the Indians at some early time, and that, while they owned it, they had utilized and worshiped it as a sacred object, and thus, having been so appropriated, it had become and was, personalty in their hands, and subsequently they had abandoned it, and, subsequently to that in turn, the defendant had found it, and thus, becoming the finder of personalty and, as such, owner, the defendant was entitled to it as against the owner of the realty upon which it was found. You will note that the burden now rested upon the appellant to show that this meteorite had been owned by the Indians and that they had abandoned it. The justice of the supreme court said in effect that, in physical appearance, the meteorite was in the shape of a huge mushroom, or an inverted bell, in dimensions 7 feet by 10 feet across the top and 4½ feet thick, and, when found, was resting with its smaller end upon the surface of the Earth, not embedded in it, but within a saucer-like depression, with hazel bushes growing about it. Its position was on the top of a knoll or eminence, with an incline in every direction, except the north. In its top, as it rested in place, were numerous cavities, or "pot-holes" as they were termed, of larger or smaller dimensions, some of them being 14 inches in depth, the whole mass being corroded, rusty, and moss-grown. Granite boulders were found in proximity to it.

The court, in looking for a precedent to guide them in determining this case, cited and quoted freely from the foregoing case of Goddard *v.* Winchell, and accepted the decision in that case as the governing law in such matters. The court recognized that there was a distinction to be made, by reason of the fact that this meteoritic mass was discovered distinctly on the surface and not beneath it; and so the justice stated that, in proximity to the place where it was found, there were granite boulders lying on the Earth, which would indicate that it might have been deposited there thru the instrumentality of an ice flow, even tho it was apparently of meteoritic origin; and that the cavities in the crown may have been the result of erosion by the enginery of the water as well as that of

oxidation thru fervent heat; and that this circumstance would certainly account for its position on the surface of the Earth, and not beneath it. It may, however, have been left there, even tho it may have been thrown from out of the Earth by a volcanic eruption, after having once been deposited as a meteorite. There is one thing sure about the inquiry, and that is that the mass was, after all, one of nature's deposits, and, presumptively, it was primarily a part of the soil or the realty upon which it was discovered, and the plaintiff's case was made *prima facie,* when it was shown that the meteorite, whether of meteoritic or glacial origin, was resting upon his land, for, without proofs showing severance from the land and appropriation, it existed in a state of nature and partook of the realty as iron ore would partake of the realty, whether found upon or beneath the surface of the Earth. So the burden rested upon the defendant to show by competent proof that the Indians had at some time appropriated the meteorite and later had abandoned it. The testimony introduced thru these Indians, as witnesses, to establish this conclusion is of interest, even tho it constituted very little substantial or competent proof of ownership at any time, by them, of the meteorite.

[*To be continued*]

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Comet Notes

By G. VAN BIESBROECK

There are no comets under observation at this time. An attempt by the writer to locate the expected PERIODIC COMET PONS WINNECKE has not met with success so far. Evidently the object is still too far from perihelion to be seen at all. However, its distance is decreasing and it should come before long in reach of larger telescopes.

Except for the short-lived COMET BERRY, which was only seen a very short time last September, no new comets have been announced for the last ten months. A great number of professional as well as amateur astronomers have had their lives affected by the sad world events and this has evidently its repercussion on scientific productivity.

Williams Bay, Wisconsin, March 13, 1945.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Irregularities in Light Curve and Period of S Aquilae: In the progress of the more or less detailed study of long-period variables being carried on by the Recorder, numerous instances of irregularities in form of light curve and in period have been noted. A particular case is that of S Aquilae, one of those stars with not too great an amplitude, and of the shorter period type.

Observations were begun on S Aquilae by Baxendell in 1863, followed later

by Knott and Schoenfeld. Early in the present century, observations were started at Harvard, and were diligently continued by the American and British variable star observers. Thus, we have an almost continuous series of observations from 1863 to date, except for the ten years between 1894 and 1903.

About the year 1883 the regular succession of maxima and minima was considerably disturbed when the star presented a maximum where a minimum was due, and *vice versa*. This discontinuity recurred at intervals until 1905. Regrettably, the lack of observations from 1894 to 1903 prevents us from having a knowledge of what happened to the star in those years.

Although the light curve has shown evidence of irregularities in the past forty years, there are no marked cases of inversion of maximum and minimum as in earlier years.

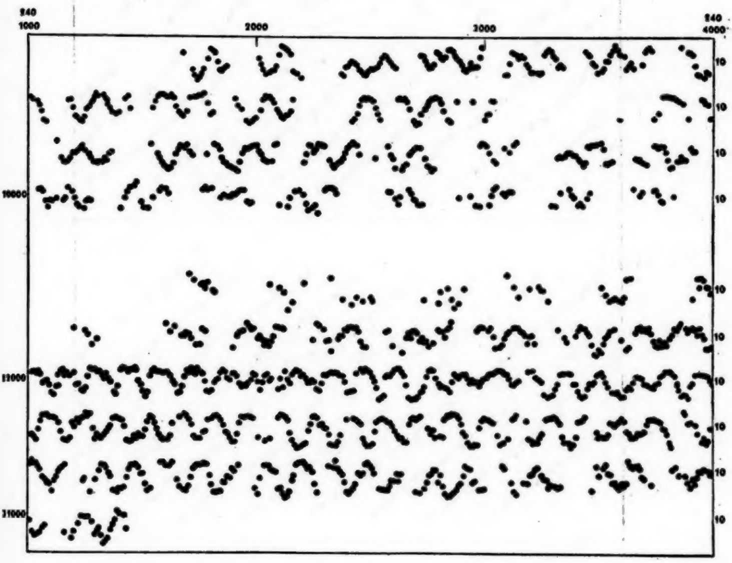

FIGURE 1

TEN-DAY MEANS OF OBSERVATIONS OF S AQUILAE, 1863-1944

S Aquilae, like some other long-period variables of similar range and of the shorter periods, presents light curves showing marked differences in form between maxima. Whereas in some instances the maxima are frequently narrow and sharp, others appear to be decidedly broad and flat. The same seems to follow for the minima. And there appears to be no regularity to such changes in form of light curve. Although the mean light curves derived from all observations made over the years appear to be of the sine curve type, with form of maximum and minimum about the same, and rate of rise and fall about equal, mean curves derived at intervals of about ten years show a dissimilarity in general shape, as pointed out for the individual curves.

The period which best fits the observations is 146.34 days, derived from

maxima as well as minima.

The running light curve covering the eighty years under discussion is shown in Figure 1, plotted from ten-day means. In Figure 2 is shown the continuity of dates of maximum and minimum, respectively; the upset in the regularity of maxima and minima being noted by the breaks in the curves. In Figure 3 are shown the ten mean light curves, together with the combined curves of I to V, and VI to X, respectively.

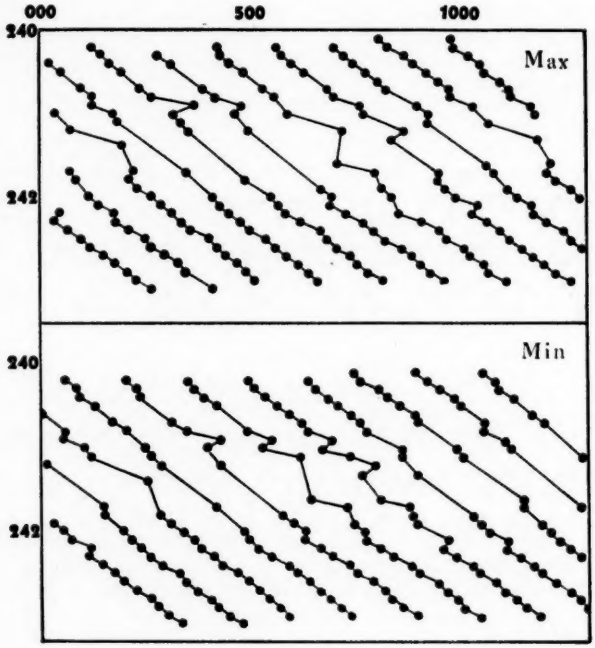

FIGURE 2

DATES OF MAXIMA AND MINIMA OF
S AQUILAE SHOWING IRREGULARITIES

The R Coronae Borealis Variables: The erratic variable R Coronae Borealis is once again on what appears to be another drop to minimum. Whether it will fade away to invisibility, except in the largest telescopes, or merely decrease a magnitude or two and then return to full maximum brightness, remains to be seen. This star has been known to present a preliminary slight decrease in light before getting off to a real drop to a faint minimum.

The present decrease was first reported late in February by Mr. D. W. Rosebrugh, of Waterbury, Connecticut, and later independently confirmed by Mr. C. F. Fernald, of Wilton, Maine.

The last drop to minimum began in October of 1942 when the variable reached the 12.5 magnitude—a decrease of six and one-half magnitudes. R Cor-

onae Borealis on that occasion remained below normal maximum brightness for nearly a year, with an attempted rise to maximum one month after minimum had been attained. This star, although now rather unfavorably placed for observation, requires close attention.

SU Tauri, after having been below normal maximum brightness since March, 1944, is almost back again to full brightness. S Apodis is also slowly increasing in light, having attained magnitude 11.8 in January. RY Sagittarii is hovering around the eighth magnitude on its way back to normal maximum brightness.

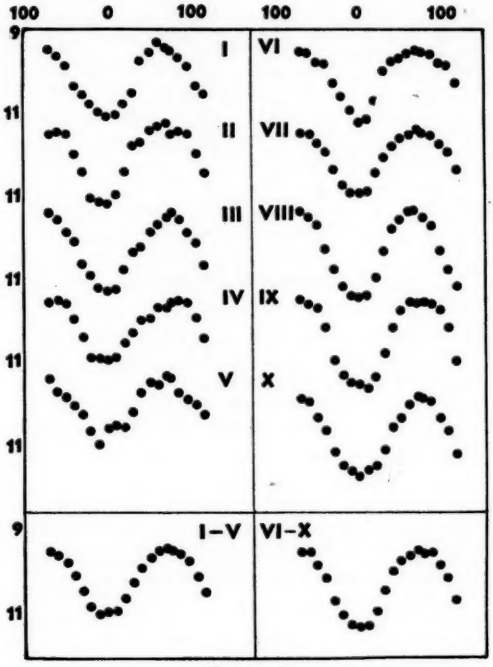

FIGURE 3
MEAN LIGHT CURVES OF S AQUILAE

Three SS Cygni Type Variables: SS Aurigae has had two well-defined maxima during the past three months, one of the broad type, about December 12, and one of the narrow type on January 16. U Geminorum was observed at a broad type maximum late in February, while SS Cygni passed through a broad maximum late in December, and a narrow type maximum late in February.

Observations for January and February: A total of 3979 observations was contributed by 38 observers during January and February, as listed herewith:

	January—1945—February					January—1945—February			
Observer	No. Var.	No. Ests.	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.	No. Var.	No. Ests.
Boone	...	...	3	3	Buckstaff	...	...	4	5
Bouton	10	18	6	7	Cousins	50	83	...	...

Observer	Var. No.	Ests. No.	Var. No.	Ests. No.	Observer	Var. No.	Ests. No.	Var. No.	Ests. No.
	January—1945—		February			January—1945—		February	
Cragg	6	15	8	25	Mary	46	115	19	48
Dafter	...	...	9	33	Mount	4	8	9	20
Duffie	4	4	22	29	Nadeau	23	25	66	66
Fernald	255	486	224	408	Oheim	53	111	73	128
Ford	34	38	5	5	Oravec	9	48	9	42
Garneau	5	6	...	...	Parks	20	33	22	35
Gossner	1	3	24	56	Peltier	20	24	111	150
Harris	31	31	15	15	Renner	5	7	3	3
Hartmann	142	149	106	110	Rosebrugh	20	134	21	173
Holt	112	178	103	120	Schoenke	10	10	7	7
Howarth	16	16	17	17	Sill	61	61	54	54
Hutchings	...	...	7	18	Stowe	...	...	12	38
Kearons	41	70	...	...	Vohman	14	20	...	...
Kelly	12	19	13	15	Webb	7	9	...	...
de Kock	66	256	67	557	Weber	40	40	40	40
Labrecque	7	14	...	...	Weitzenhoffer	4	12	5	28
Liller	1	4	28	48					
Luft	...	...	8	32	Totals		1647		2332

March 13, 1945.

General Notes

Mr. Gerald M. Clemence has been appointed Director of the Nautical Almanac Office, U. S. Naval Observatory. Dr. Paul Herget succeeds Mr. Clemence as Assistant Director.

Fifty Years Ago

In the February issue (p. 96), under this heading, we reprinted a portion of a paper on Mars by Percival Lowell, which had appeared first in the February issue of 1895, just fifty years earlier. That paper was continued in the April, 1895, issue, giving special attention to the *oases*. Inasmuch as the question of the so-called canals of Mars still constitutes an item of interest and study, we are continuing here the early, almost the first, discussion of them by the eminent proponent of their reality. EDITOR.

MARS.

PERCIVAL LOWELL.

OASES.

In the last paper I mentioned a certain feature of the canal system which is worth considerable attention—the striking propensity of the canals to rendezvous at several points.

If one were to draw lines at haphazard over the surface of a globe, he would find that although crossings of two lines would occur plentifully enough, crossings of more than two lines would occur practically never. Indeed if the lines were fine enough, multiple meetings could not take place at all, no matter how great the number of the lines. For the chance against any third line crossing two others at their point of intersection would be millions to one.

In the case of the Martian network, however, we are presented with a whole system of such improbabilities. Not only do we mark instances

of more than two canals meeting at a point, but associability turns out to be the rule not the exception. An occurrence, therefore, a single instance of which would, in the event of lines drawn at haphazard, be one of the highest unlikelihood, happens habitually in the case of the lines on Mars. But haphazard is merely another word for lack of connecting cause. As, therefore, it is many millions to one against such a system being the result of chance, there must be a rational connecting cause under the observed physical connection. In other words that the canals should thus meet is somehow part and parcel of their very existence.

We may mark incidentally that this fact alone is fatal to the hypotheses that the lines are rivers or glaciation cracks, or even furrows ploughed by visitant meteorites. For in all these hypotheses the meeting points are not points in the argument. But as the meeting points are essential to the system, as we have just seen, and not haphazard irrelevancies, no theory about the canals can leave them out of account. Any theory that attempts to interpret the canals must *ipso faco* explain why they meet.

Now the most obvious explanation of such association that occurs to one who has not seen the canals, is that the canals are fissures radiating from centres of explosion or contraction. This idea as naturally commends itself to anyone before he has seen the canals, as unfortunately it does not commend itself after he has done so. For the lines on Mars bear no resemblance to a system of cracks of the sort; such, for example, as we see in the case of Tycho in the Moon. The look of the two systems is as unmistakably diverse as possible. Certainly no analogy whatever is suggested by the lines themselves; it takes a mind unbiased by actual observation to conceive it. To mention but one point of dissimilarity since that is itself sufficient, the lines of Mars are strikingly of the same size throughout. This of course would be impossible under any process of bursting or shrinkage.

From what the lines cannot be, we may turn to what they possibly are. In the first place we may begin by saying that the lines do not go from the centres of the system but that they go to them. This statement has the merit of seeming utterly incapable of proof on the face of it. For the lines are stationary quantities, and do not move at all one way or the other. *E pur si muove* for all that.

A justification of the paradox introduces us to one of the most important outcomes of this year's observations—the oases.

The law regulating the rendezvousing of the canals at certain points finds its sanction in what turns out to be there. For it appears that there is something besides impalpable constrainment in the cause that thus attracts the canals toward one another. The meeting places are not simple junctions of the canals; there is something at the junction. This something shows itself as a round spot.

Scattered over the orange-ochre groundwork of the continental regions of the planet are any number of dark round spots. How many there may be it is not possible to state as the better the seeing the more of them there seem to be. I have mapped thirteen as existing on the single line of the Eosphoros, Eumenides and Orcus, including the Lake of the Sun and the Trivium Charontis, with a similar state of things elsewhere.

In spite, however, of their great number there is no instance of one occurring unconnected with a canal. What is more there is apparently none which does not lie at the junction of several canals. For though one or two as yet appear to be provided with but a single canal for connecting link with the rest of the dark areas, so many more have thus appeared at first and then later been found to have other canals running to them, that it seems more than probable that all are so circumstanced.

Reversely all the junctions appear to be provided with spots. In the case of the more difficult canals the spots are not evident. But inasmuch as the canals are easier to see than the spots such invisibility is to be expected; and in the case of crossings of the more conspicuous canals there is apparently no omission. Indeed to be spotless appears by its very nature to be an impossibility for a junction.

The spots, therefore, are part and parcel of the canal system. Secondly, they are terminal phenomena of the same.

Next in suggestiveness to the uniformity of their position, is their apparent uniformity of form. There is reason to believe that they are always round. For the better they are seen the more perfectly circular they look. In the worst seeing that renders them visible at all they show as irregular patches. As the seeing improves they contract into large round dots until under the best definition I have seen the most conspicuous among them, the Phoenix lake, quite startlingly circular, as if purposely so.

In size too they have a certain uniformity. Of those connected with the single canals, the largest are about 150 miles in diameter, the smallest about 70—the smallest that is yet seen. But the smaller are in the minority. Most of the spots are about 120 miles across, and bear a most suggestive family resemblance to one another.

When they are plotted upon a globe, they and their connecting canals make a most curious network over all the orange-ochre equatorial parts of the planet, a mass of lines and knots, the one marking being as omnipresent as the other. Indeed the spots are as peculiar and distinctive a feature of Mars as the canals themselves.

Premonitory systems of visibility, rather than views, of one of the spots, the Tithonius Lake may be seen in the best drawings made in the sixties, those by Lockyer, Kaiser and Dawes—the drawings of all three of these observers growing more and more admirable the closer they are studied. Several other spots have since been seen by Schiaparelli but it was not till 1892 at Arequipa that the spots were seen in anything like their true numbers. At Flagstaff this year I have been able to detect many more of them, to, I think, detection of their character.

The spots first became visible this year where they were especially prominent in 1892, in the region about the Solis Lacus. The Lake of the Sun, indeed, is surrounded by a cordon of canals beaded by spots. All the spots showed round with the exception of the Tithonius Lake which appeared oval, but in a drawing by Schaeberle made this year, two round spots take the place of the Tithonius Lake. This leads me to believe that the oblong look is due to quality and that the lake is therefore no exception to the rule; furthermore I have had a suspicion of two canals leading to it which hints at the same thing.

It was not, however, until later in the season when the Eumenides-Orcus began to show beaded that I first suspected the true character of the spot phenomenon. Suspicion indeed attaches to the very form of the spots. For, as we have seen, they are round. That is, they are convex not concave to the converging canals. Now were the spots natural enlargements of the canals at their termini, they should be star-shaped, that is concave to the canals. That they should on the contrary be convex seems inexplicable by any natural process of development.

We come now to the most suggestive feature about the spots: namely, that like the canals, they somehow grow. Like the canals they are not equally visible at all seasons. Indeed at certain seasons the rank and file of them are not visible at all; and this invisibility is not a matter of distance or obscuration but is intrinsic to the spot itself. Then just as the canals become evident so the spots gradually grow into recognition.

The history of the development is similar in both cases. Where the canals first make their appearance, there likewise are the first spots seen. The most southern spots, those nearest the south pole are evident early in the Martian season. At the end of last August, for example, the spots about the Lake of the Sun were perfectly visible; while at the same time those along the line of the Eumenides-Orcus were invisible; the same relation holding between the canals in the two parts of the planet. As the season advanced the more equatorial spots began to show, beading the Eumenides-Orcus, the great through line to the Trivium Charontis from the Solis Lacus region, the Pyriphlegethon running from the same region a more southerly course, and the perfect network of canals between the two. A good instance of the change that had occurred between the last of August and the early part of November is to be found in the relative intensities of the Phoenix Lake, the spot at the junction of the Iris and the Gigas and the spot where the Steropes (a newly discovered canal to the north of the Gigas) and the Nilus meet. In August the first was very conspicuous, the second only moderately so and the last barely discernible. By November the Phoenix Lake had become less striking, the upper Ceraunius spot relatively more so, and the lower one nearly as evident as the upper one had been.

This shows that the change is seasonal, but it also shows that the change sweeps gradually across the planet's face as a unit. For the lower Ceraunius spot lies in latitude 27° north. In other words the quickening is not local but depends in some wise upon the melting of the south polar snows.

Another important point about the spots is that their development is, apparently, not quite synchronous with that of the canals but follows it. One marks the canals first and the spots afterward and considering that the spots are much larger than the canals such priority in appearance might well be reversed. The spots are, therefore, in the first place seasonal phenomena, and in the second place phenomena that depend for their existence upon the prior existence of the canals.

A third feature in their development is that they grow not so much in area, apparently, as in depth of tint. The larger ones especially seem to suffer no perceptible change in size from the time of their first appearance. They simply darken as time goes on.

Now when we put all these facts together, the presence of the spots at the juctions of the canals, their apparent invariability in size, their seasonal darkening, and last but not least the resemblance of the great equatorial regions of Mars to the deserts of our Earth, one solution instantly suggests itself of their character, to wit: that they are oases in the midst of that desert.

Here then we have an end and reason for the existence of canals and the most natural one conceivable—namely that the canals are constructed for the express purpose of fertilizing the oases. When we consider the amazing system of the canal lines we are carried to this conclusion as forthright as is the water itself; what we see being not the canal itself indeed but the vegetation along its banks, a theory propounded some years ago by Professor W. H. Pickering. Of course all such evidence of design may be purely fortuitous and with about the same probability, as it was put happily the other day, that a chance collection of numbers should take the form of the multiplication table.

But the shape of the spots hints at more. For there is no good reason in the course of nature why in such circumstance they should all apparently be round any more than they should all lie at the intersections of the canals. But there is good reason for both facts if the spots be cases of assisted nature. If they be districts artifically fertilized by the canal system the larger would naturally be found at the intersections of the canals and intelligence would conduct to the circular form, in order to use the greatest amount of space for the least expenditure of exertion. For the circle is the figure that encloses the maximum area for the minimum average distance from its centre to any point situated within it. And such inference of design is in keeping with the curiously systematic arrangement of the canals themselves. Just as the canal takes the shortest distance from one point on the sphere to another, so the oasis encloses the greatest space at the least trouble. The whole system is trigonometric to a degree. If Dame Nature be at the bottom of it all she shows on Mars a genius for civil engineering quite foreign to the disregard for prosaic economy with which she is content to work on our own work-a-day world. Her love for elementary mathematics is evidently greater than is commonly supposed, a private passion which on tenantless Mars she is able to indulge unhampered by fear of unseemly ridicule.

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Publications Received.—The publishers of POPULAR ASTRONOMY hereby acknowledge receipt of the following named publications and express their great appreciation of the courtesy shown on the part of those who have sent them.

Contributions from the Mount Wilson Observatory:

No. 689. "Radial Velocities of 283 Stars of Spectral Classes R and N," by Roscoe F. Sanford.

No. 690. "Spectroscopic Observations of 48 Librae," by Paul W. Merrill and Roscoe F. Sanford.

No. 691-692. "Investigations on Proper Motion. XXIII. The Proper Motion of the Cluster *h* Persei."

"The Photographic Determination of Stellar Parallaxes with the 60- and 100-inch Reflectors: Nineteenth Series," by Adriaan van Maanen.